Cost Action E47

Forest vegetation management in Europe

Current practices and future needs

Edited by Ian Willoughby, Phillipe Balandier, Niclas Scott Bentsen,
Nick McCarthy and Jenny Claridge

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Introduction

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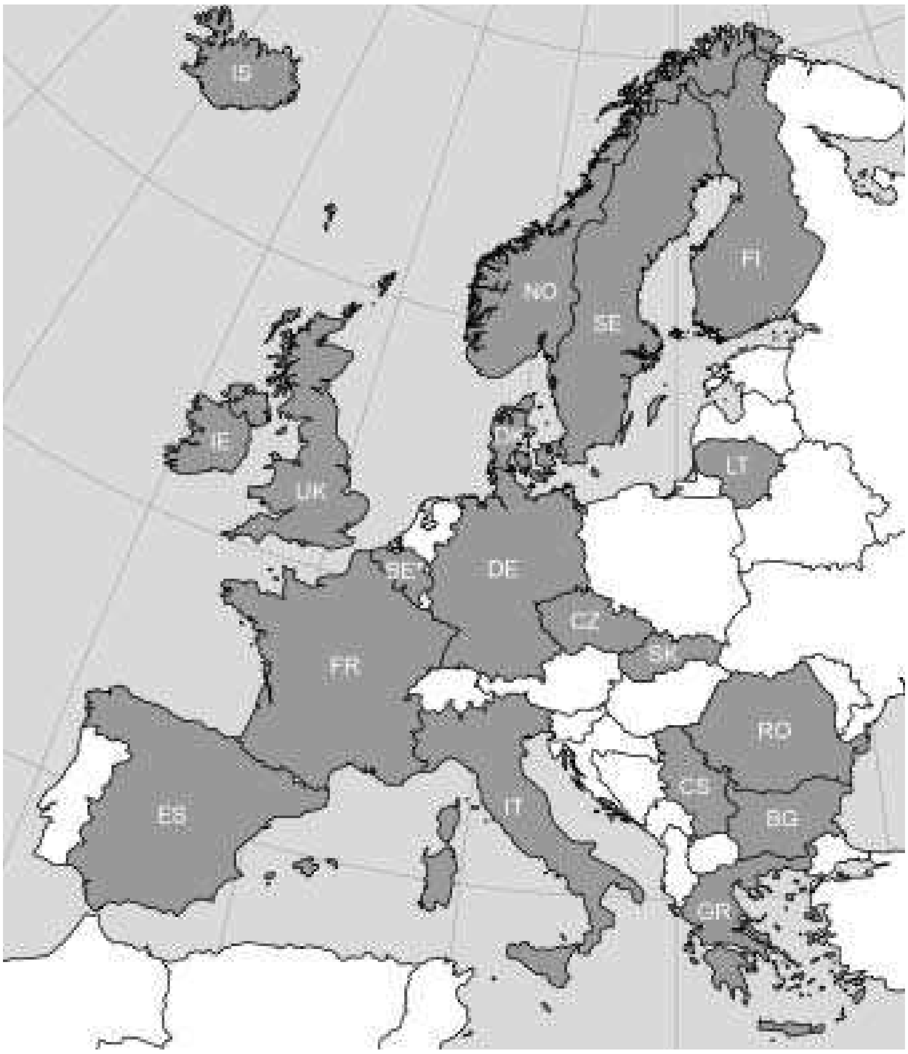
Background to COST Action E47

The European Network for Co-operation in the field of Science and Technology (COST) funds the development of scientific networks of excellence on a wide variety of topics and disciplines. COST Action E47, part of the Forestry Domain, was formed in 2005 (http://www2.clermont.inra.fr/cost-e47/index.htm). The main objective of the action is to help forest managers reduce their dependence on using herbicides in Europe's forests by facilitating and co-ordinating the development of sustainable, environmentally sound, socially acceptable and economically viable alternatives based on sound forest management principles. The Action has brought together practitioners and scientists from 19 European countries (Figure Intro. 1) to share expertise and experience and the latest scientific advances in the field of forest vegetation management. It has also funded participation and input by experts from South Africa and the USA for the benefit of forest science in Europe. The key benefit of COST E47 has been the exchange of knowledge from otherwise unconnected scientists who share many of the same national challenges and research priorities.

Figure Intro. 1 | Cost Action E47: the participating European countries.



CZ Czech Republic
DK Denmark
FI Finland
FR France
DE Germany
GR Greece
IS Iceland
IE Ireland
IT Italy
LT Lithuania
NO Norway
BG Republic of Bulgaria
RO Romania
CS Serbia
SK Slovak Republic
ES Spain
SE Sweden
UK United Kingdom
BE* Belgium
*Participant in early stages only.

The primary mechanism for achieving this exchange of information has been through participation in a series of scientific field meetings that examined research and operational practice in a range of contrasting European conditions. This has led to the formation of several lasting collaborative networks that have resulted in the development of several proposals for future European research.

This publication provides a record of this co-operation within Europe in the field of forest vegetation management, and it forms one of the key outputs of COST Action E47. The aims of the publication are:

- to provide a summary of the current ‘state of the art’ as it applies to forest vegetation management in Europe for scientists, practitioners and policymakers, affiliated to state, non-governmental or private commercial organizations;
- to document existing forest weed control practices across Europe, and hence provide a resource of alternative solutions for individual countries sharing similar conditions and challenges;
- to identify common information gaps and future research needs, and hence potential future areas of collaboration for forest vegetation management scientists across Europe, along with barriers that may need to be overcome to achieve that aim.

As far as possible, each country report (presented as a chapter) follows the same basic structure to allow comparisons to be easily made. A concise summary of the country and the history and management of its forest resource is followed by a review of pesticide use in the country, along with the policy environment that governs it. Each chapter is then organized into three main sections that mirror the COST Action E47’s organization into three Working Groups, to provide a review of the current state of the art for forest vegetation management in each country in terms of approaches to:

- treatments and alternatives
- knowledge of ecosystem impacts
- attitudes of wider society.

This publication therefore provides for the first time an overview of forest vegetation management as practised across 18 European countries in the early 21st century. It is hoped that it will provide a valuable reference work for the future.

Overview of the country contributions

Europe’s woodlands

Europe’s forests have a long history of human intervention. The elimination of predators, clearance of land for agriculture, introduction of domestic grazing stock, utilization of forests for wood products, and the introduction of invasive and non-native species have all disturbed natural cycles of woodland regeneration. As a result, natural regeneration of forests is now less likely to succeed without some form of human intervention. One of the key problems facing young regenerating tree seedlings is competition from weed vegetation for the acquisition of major resources like light, water and mineral nutrients.

The country contributions suggest that in the majority of woodlands across Europe, as in other regions across the world, managing competing vegetation to favour tree seedlings at the expense of weed species is a critical silvicultural operation. Tree regeneration may be impossible or at the very least severely delayed without some form of intervention, be it through management of an existing overstorey of trees to favour seedlings or to create conditions where weeds may compete less strongly, manipulation of browsing pressure, or the direct physical control of vegetation.

In many countries, the historic sequence of changing forest use has tended to follow a broadly similar pattern of initial exploitation and degradation that is succeeded by restoration primarily for timber production. This has been followed more recently by the development of policies designed to protect forests and to enhance their multi-functional management for a variety of objectives, which include protection of biodiversity, the sustainable production of timber or woodfuel, mitigation of climate change, and the provision of a recreation resource for an expanding and increasingly urbanized population. But whatever the overall objectives for which a woodland is managed, the contributions suggest these aims would often be impossible to achieve economically or over an acceptable time frame without the adoption of appropriate vegetation management practices.

The impacts of weed competition

Throughout Europe the impact of weed competition on the growth and survival of tree seedlings is consistently referred to by all contributors to this book; however, the precise nature of competitive effects has only been studied in detail in a few countries. Both positive and negative impacts on tree growth are noted, the precise nature of any particular effect depending on local site conditions such as the specific weed and tree species present and availability of resources. Often the interaction of these factors is dynamic through time. Because the magnitude and precise nature of effects is so dependent on local site conditions, with our current level of knowledge, it is difficult to make broad generalizations that can be applied to a wide range of sites across Europe. However, it is possible to identify some general trends about the most problematic weed species and situations.

Across all countries, grass and herbaceous species are identified as the main competitors on regeneration sites. Grasses such as *Calamagrostis epigejos* (wood small-reed), *Deschampsia flexuosa* (wavy hair-grass) and *D. cespitosa* (tufted hair-grass), and herbaceous species such as *Pteridium aquilinum* (bracken), *Epiliobium* sp., *Senecio* sp. and *Urtica* sp. (nettles) are commonly cited as problem species. Woody species such as *Rubus fruticosus* agg. (bramble), *Ulex europaeus* (gorse), birch (*Betula* spp.) and a range of other broadleaved trees are also often identified as problematic in later stages of the regeneration cycle, particularly in conifer regeneration. In drier regions of southern Europe where competition from grass and herbaceous species may be less of an issue, woody vegetation also contributes to increased fuel loads and raises the risk of fire.

Another reported trend is that the variety and competitiveness of weeds increases with soil fertility, and this is a particular challenge for afforestation of ex-agricultural sites. Particular alien invasive weeds are also identified as common problems in several countries, examples include *Rhododendron ponticum* (rhododendron), *Impatiens glandulifera* (Himalayan balsam) and *Robinia pseudoacacia* (false acacia).

The use of pesticides in Forestry

Herbicides offer an effective means of controlling all problem species and classes of weeds identified. However, there has been increasing pressure in recent years to reduce reliance on chemicals. Policy drivers for this pesticide reduction fall into three main categories. Firstly, several countries report national policies restricting pesticide use. Secondly, independent forest certification schemes such as those approved by the Programme for the Endorsement of Forest Certification schemes (PEFC) and the Forest Stewardship Council (FSC) are becoming increasingly important in many countries, and these schemes impose restrictions on pesticide use. Thirdly, European Union policy on pesticide approvals has led to a review of the safety and efficacy of all registered pesticides; lack of data, adverse data, and commercial decisions have led to the withdrawal of many active ingredients, such that in some countries only a handful of active pesticides remain legal to use in forests.

It is difficult in practice to quantify accurately on a European scale how effective these policies have been in restricting the use of pesticides in forestry. One issue has been the limited amount of comparative evidence available on the level of pesticide usage in forestry across Europe. For this reason, as part of the work of the COST Action, contributors compiled estimates of pesticide use by their country's forestry and agricultural sectors (Table Intro. 1). Although the estimates are only indicative and do not give details of trends over time, they nevertheless provide a useful comparison of participants judgements of usage throughout Europe. Application rates reported in forestry were very low, in the range of 0.0001 – 0.6 kg active ingredient (a.i.) ha^{-1} yr^{-1}. By comparison, average application rates in agriculture were in the region of 0.3 – 1.84 kg a.i. ha^{-1} yr^{-1}. Use in forestry was usually less than 1 % that of agriculture on an annual area basis. In some countries with historically low levels of pesticide use, contributors predict that usage was likely to increase due to rising labour costs, making labour intensive non-chemical methods, such as motor-manual cutting and hand cultivation, less economic. In most countries where chemical use has been common in the past, the reports suggest that the more recent trend is for a reduction in pesticide use: in some countries the reduction has already been very substantial. However, despite the prevailing policy environment, every country that submitted data reported that pesticides were still used to some degree in some of their forests.

Table Intro. 1 | Estimated annual pesticide use in agriculture and forestry across Europe.

Country	Land area (ha)	Forest area (ha)	Total pesticide applied (kg a.i. yr^{-1})	Total pesticide applied in forestry (kg a.i. yr^{-1})	Average applied in agriculture (kg a.i. ha^{-1} yr^{-1})	Average applied in forestry (kg a.i. ha^{-1} yr^{-1})
Czech Republic	7 887 000	2 647 000	4 325 123	1 704 847	1.01	0.6441
Denmark	4 309 800	534 000	3 572 000	n/a	1.45	n/a
Finland [a]	30 414 000	26 280 000	1 859 000	3 000	0.39	0.0001
France	54 900 000	15 500 000	n/a	n/a	n/a	n/a
Germany	35 702 217	11 075 799	n/a	n/a	n/a	n/a
Greece	13 196 700	6 513 000	9 606 200	13 200	1.70	0.0020
Iceland	15 000 000	149 000	n/a	30	n/a	0.0002
Ireland	6 976 110	697 850	1 156 860	4 101	0.24	0.0059
Italy	30 165 801	10 467 533	n/a	n/a	n/a	n/a
Norway	32 380 000	12 369 000	523 500	650	0.50	0.0001
Lithuania	6 530 000	2 091 000	1 055 280	6 780	0.30	0.003
Republic of Bulgaria	11 098 700	4 076 464	4 928 947	4 947	0.77	0.0012
Romania	23 830 000	6 790 000	n/a	10 799	n/a	0.002
Serbia	8 840 000	2 360 000	n/a	32 580	n/a	0.014
Slovak Republic	4 903 400	1 931 645	3 576 000	837 000	0.70	0.433
Spain	50 536 000	16 867 000	96 359 000	n/a	n/a	n/a
Sweden	41 000 000	27 200 000	1 795 000	4 900	0.39	0.0002
UK [a]	24 291 000	2 825 000	33 728 000	34 000	1.84	0.0120

Figures given are indicative estimates only, and may be based on different base years and country assumptions.
Refer to individual country chapters for basis of estimations.
[a] Estimates for Finland and the UK exclude the use of urea fertilizer as a stump treatment.
n/a: data not available; a.i.: active ingredient.

These data tend to challenge the view that the success of some European countries in reducing reliance on pesticide use in their forests prove that it is practical to immediately stop using pesticides entirely elsewhere in Europe. Such an assertion fails to take account of the fact that even in countries with very low levels of pesticide use within forests, some situations remain where the adoption of wholly non-chemical approaches to weed management have proved impractical. The contributions in this book suggest that the switch to more expensive non-chemical methods has been most successful in state-owned forests, or subsidized private forests, where sufficient additional funds are made available specifically for that purpose by governments. However, even in these cases, there are particular situations where herbicides continue to be used, such as during the conversion of sites from agricultural production to forestry, the control of high productivity grass species on more fertile soils particularly after clear felling where continuous cover systems are impractical, the control of specific invasive species, and intensive weed control in forest nurseries. Consequently, any decision to adopt an alternative vegetation management system that is practised elsewhere in Europe has to take account of the type of forest, management system, site fertility and climate and weed species, along with the prevailing economic environment.

Non-chemical weed management

Contributing countries with broadly similar weed species, climate and economic conditions have adopted similar approaches to the non-chemical management of competing vegetation. The main non-chemical methods of control practised are silvicultural manipulation, cultivation and cutting weeds by machine or hand tools. There are few if any examples of a truly novel, fully-developed and effective form of weed management being practised by a single country and not taken up by others with similar prevailing environmental and economic conditions and labour costs. That is not to say there are no differences between the contributing countries. For example, the cutting of vegetation using hand tools is labour intensive, and hence often more widely practised in relatively recent EU accession states, where labour costs are currently comparatively low. Cultivation appears to be most effective and hence most widely practised on the driest and least fertile sites. Mulches are used on a small scale, mainly in countries where higher value roadside or arboricultural plantings are common. Biological control is not yet widely used, although grazing is an important tool in some southern European countries. Stand manipulation is most widely practised in the countries with a high proportion of forest cover and a long tradition of silviculture supported by forest policy. The environmental impacts of non-chemical methods of control do not seem to have been extensively studied in any of the countries, but it is widely assumed that they are likely to be less damaging than the use of herbicides, for which there are known problems if misused. The main barriers to the further adoption of proven methods of non-chemical weed management therefore seem to be excessive cost or perceived lack of efficacy in particular conditions.

Despite the prevailing view that public attitudes in Europe have driven the shift away from using herbicides for vegetation management, the country contributions note little active research focusing on these social issues. This may be because funding agencies perceive no need to further examine the assumed prevailing view that herbicide use is undesirable. Alternatively, it may be that understanding the values underlying people's attitudes towards different approaches to forest management remains a key issue, but that this is an under-researched topic that was outwith the core discipline of most participants in this COST action. Building better linkages to interested socio-economic researchers would be an important step forward in the future.

Future European research collaboration

The priorities

Several common information gaps relating to forest vegetation management in Europe can be identified from the country contributions. From these, four high priority areas for future European research collaboration have been identified.

- **Alternative control methods** There is a clear need for collaborative research to develop novel, cost-effective, low-impact alternatives to herbicides for use on a range of woodland types, situations and weed problems under current and future climate change scenarios. Methods under development in individual countries that should be integrated more widely across Europe include the use of cover crops, nurse species and direct seeding; mulches based on biodegradable materials; biological control of specific problem weeds; grazing as a management tool; production of more weed tolerant planting stock; improved techniques for the mechanization of cutting and cultivation within woodlands; and the development of more selective, lower impact herbicides for forest nurseries, Christmas tree production and woodland regeneration.
- **Ecosystem responses** Joint studies are required into the ecology and competitive effects of both specific problem species such as *Rubus fruticosus* agg. and *Pteridium aquilinum*, and of functional groups of weeds. Studies of particular species across several countries may allow models to be developed for predicting the impact of weeds on tree seedlings in relation to different silvicultural treatments and alternative climate change scenarios.
- **Impacts** Quantification is needed of the relative environmental impacts of non-chemical methods, in the context of known impacts of pesticide use.
- **Social issues** Investigations are needed into the underlying values that drive public perceptions of different vegetation management methodologies, and research is required to explore the linkages between perceived impacts of forest vegetation management and the benefits it provides.

However, a lack of funding for multinational collaborative research, and a focus on theoretical rather than applied forest science, are identified by the contributors as significant barriers to further progress towards achieving more sustainable vegetation management practices in Europe.

Conclusions

It is clear from this review that if a ban or a widespread severe restriction on the use of pesticides in forestry across Europe was to occur in the near future, particularly if it were to be based on inaccurate assessments of hazard or risk, this could have significant and unintended negative impacts on the health of many of Europe's forests, unless considerable extra funding was made available to forest managers to adopt existing more expensive, non-chemical weed control methods. The development of more cost-effective and practical guidance for managers across Europe on non-chemical control methods can best be brought about by future collaborative research into more sustainable and holistic methods of managing forest vegetation, through the identification of silvicultural approaches to reduce or eliminate pesticide use, and through gaining a better understanding of the fundamental mechanisms and impacts of competition. Such a move towards integrated forest vegetation management would support important new European policy initiatives on the sustainable use of pesticides, and benefit Europe by ensuring its forests are more resilient to climate change, and are being managed and regenerated in a more sustainable fashion, to maximize biodiversity and other benefits for current and future generations.

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Eighteen of the nineteen nations who participated in the COST Action have contributed to this publication (due to staff relocations, Belgium was only able to participate in the early stages of the Cost Action). Each chapter reflects a considerable commitment, not only from the authors, but also from their colleagues and collaborators who provided information, responded to surveys, drafted, checked and edited contributions in what, for the vast majority of countries, was a second language. We acknowledge the commitment of all these contributors and their supporting colleagues.

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As its Chair, Nick McCarthy is to be especially thanked for the burden he has shouldered in co-ordinating, encouraging and leading the work of COST Action E47 with such patience and good humour over the past 4 years.

Disclaimer

1 Czech Republic

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Country background

History

Systematic forest management in the territory of the Austria-Hungary empire, which the Czech Republic belonged to, probably began in the second half of the 18th century. From 1790, when the first data were available, the forest area increased by 665 000 ha and the forest cover increased from 25 % to 33.4 %. Recent years have seen only a slow increase. Large changes in forest ownership occurred in the 20th century. The first change followed immediately after the constitution of the independent Czechoslovak Republic (1918) when land properties of large noble families were nearly all nationalized in a so-called 'first land reform' (1920–1925). This was markedly reflected in the increased area of state forests which, up until then, had formed only 3.6 % of the area. After the Communist putsch in 1948 land properties were nationalized completely and it was only after the November revolution in 1989 that the restitution law made it possible to return these properties to their original owners (Anon., 2002). Trends to manage productive forests on the basis of 'near to nature' principles and to emphasize non-productive forest functions have since become apparent.

Climate

The mean temperature in January is -2.5 °C (range -6.8 °C to 0.6 °C) and in July 17.6 °C (range 10.0 °C to 19.9 °C). Mean annual precipitation is about 750 mm (range 450 mm to 1700 mm). The mean number of growing degree-days (above 5 °C) is around 190 (range 156 to 232).

Woodland area

Woodlands occupy 2.65 million ha or 33.6 % of the land area in the Czech Republic (Table 1.1). Only a small area of virgin natural forest remains. A summary value of average increment of the country growing stock is 17.5 m^3 ha^{-1} yr^{-1}. Around 21 000 ha are regenerated or afforested every year; a summary value of average establishment cost per ha is 65 846 CZK ha^{-1}. According to the Forest Act No. 289/1995 there are three categories of forest (Table 1.2): production (commercial) forests, protection forests (those on extremely unfavourable sites or growing below the tree limit and those with important environmental functions) and special purpose forests (e.g. in national parks, landscape protected areas, health resorts and suburban forests).

Land use	Area (ha)	Percentage (%)
Forest	2 751 586	34.9
Non-forest	5 135 309	65.1
Total	**7 886 895**	**100.0**

Table 1.1 I Forest and non-forest land in the Czech Republic. Source: *Report on the state of forests and forestry in the Czech Republic by 2006* (Ministry of Agriculture, Prague, 2007).

Land use	Area (ha)	Percentage (%)
Production forest	2 030 793	75.8
Protection forest	75 016	2.8
Special purpose forest	573 337	21.4
Total	**2 679 147**	**100.0**

Table 1.2 I Forest categories in the Czech Republic. Source: *Report on the state of forests and forestry in the Czech Republic by 2006* (Ministry of Agriculture, Prague, 2007).

A total of 680 000 ha of forests are protected in two large-scale and four small-scale categories of areas according to the Nature and Landscape Protection Act No. 114/1991. The extent of these protected categories, according to the International Union for the Conservation of Nature and Natural Resources (IUCN) protected area classification, is given in Table 1.3.

IUCN classification		Area (ha)
Ia	Strict nature reserve	370
II	National park	67 000
III	Nature monument	12 000
IV	Protected area with site management	45 630
V	Landscape protected area	555 000
VI	Protected area with the managed source use	0
Total		**680 000**

Table 1.3 I Forest area according to IUCN categories. Source: Cudlin *et al.*, (2004).

Species composition

Of the forest land, 68.7 % consists of mainly coniferous forests, 14.3 % of mainly broadleaved forests and 17.0 % of mixed forests. The main wood-producing species are *Picea abies* (Norway spruce) : 53.1 %, *Pinus sylvestris* (Scots pine) : 17.2 %, *Fagus sylvatica* (beech) : 6.6 %, *Quercus* spp. (oaks) : 6.6% and *Betula* spp. (birches) : 2.9 %.

Ownership

About 60 % of forests are publicly owned, 16 % are municipal and the balance (about 23 %) belongs to private owners (Table 1.4).

Owner	Area (ha)	Percentage (%)
State	1 599 451	59.7
Municipalities	417 947	15.6
Regional governments	5 358	0.2
Forest co-operatives	26 791	1.0
Public universities	8 037	0.3
Private	621 562	23.2
Total	**2 679 147**	**100.0**

Table 1.4 I Forest ownership. Source: *Report on the state of forests and forestry in the Czech Republic by 2006* (Ministry of Agriculture, Prague, 2007).

Silvicultural systems and forest certification

Clearfell and replant systems predominate while selection forest is practised in only 1.8 % of forests. However, natural regeneration has gained importance in recent years (for economic reasons), reaching 17 % of all forest regeneration in 2005. So-called 'high forest' (99.7 % of forest area) dominates while other forest management types such as coppice and 'middle forest' (mixed coppice and high forest) are negligible.

Pesticide use in the Czech Republic

The quantities of pesticides used in agriculture and forestry decreased dramatically after restitution and privatization of government land, in connection with price increases and reduction of reforested clearcut areas. In agriculture, consumption was as high as 2.26 kg of active substance per ha of land farmed in 1990 but by 2005 it had reduced to 1.01 kg. Table 1.5 shows present-day use of individual pesticides in agriculture and forestry and Figure 1.1 shows the decrease in herbicide usage in forestry during the past five years. As a result of various factors such as regulation (e.g. prohibition of pesticide use in protected areas according to the Nature and Landscape Protection Act No. 114/1991), a decrease in areas of artificial forest regeneration, ecologically oriented subsidies, and more effective and environmentally friendly technologies, pesticide use in forestry has slowly declined.

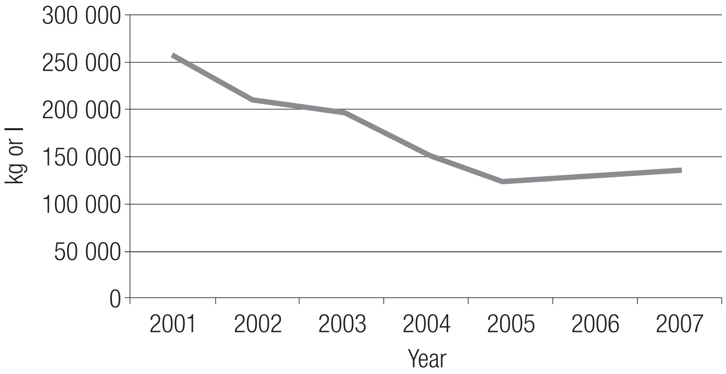

Figure 1.1 | Herbicide consumption from 2000 to 2007 (some herbicides in kg, some in l). Source: *Consumption of chemical preparations for forest protection in 2007* (Janauer *et al.*, 2007).

Table 1.5 | Consumption of active ingredients (some ingredients in kg, some in l, some in pcs – pheromone trap packings) in agriculture and forestry in 2006. Sources: Agriculture – *Czech statistics yearbook for 2006* (Czech Statistical Office, 2007); Forestry – *Consumption of chemical preparations for forest protection in 2007* (Janauer *et al.*, 2007).

Active substances	Agriculture			Forestry	
	Total	%	Per ha of land farmed	Total	%
Total	**4 589 292**	**100**	**1.0723**	**1 916 426**	**100**
Herbicides and desiccants	2 638 904	57.5	0.6166	126 239	6.6
Fungicides	841 471	18.3	0.1966	8 571	0.4
Zoocides (insecticides)	164 519	3.6	0.0384	19 321	1.0
Rodenticides	2 863	0.1	0.0007	12 155	0.6
Repellents	438	0	0.0001	1 613 843	84.2
Pheromones (pcs)				136 297	7.1
Growth regulators	741 131	16.1	0.1732		
Additives	75 115	1.6	0.0176		
Antitranspirants and means limiting harvest losses	21 121	0.5	0.0049		
Insecticide-type seed dresser	17 341	0.4	0.0041		
Fungicide-type seed dresser	86 145	1.9	0.0201		

Policy drivers and pesticide regulation

Two acts in the Czech Republic, the Nature and Landscape Protection Act and the Water Act, have reduced the use of pesticides in the landscape to a certain degree; the former in protected areas and the latter in the zones of groundwater protection. However, these areas form less than 20 % of the total area of the country.

In the Czech Republic rules of good practice in forestry have not yet been applied. On the other hand, 74 % of all forests (and almost 100 % of state forests) are managed under the terms of a voluntary certification initiative, supervised by the PEFC (Pan-European Forest Certification); however only a small proportion of owners has accepted the certification system based on near-nature forest management, proposed in the frame of the FSC (Forest Stewardship Council) by certain Czech non-government organizations (Table 1.6).

Ownership	PEFC	FSC
	Certified forest area (ha)	
State forest	1 567 394	13 230
Individual	99 382	3
Corporations	48 574	7 165
Communities	241 701	4 574
Total	**1 957 051**	**24 972**

PEFC: Pan-European Forest Certification. FSC: Forest Stewardship Council.

Table 1.6 | Status of the forest certification in the Czech Republic in 2005. Source: *Report on the State of Forests and Forestry in the Czech Republic by 2005* (Ministry of Agriculture, Prague, 2006).

Weed problems

A large variety of trees, brush, herbs and grasses are considered to be forest weeds. During reforestation of clear cut areas, the most problematic species are: the shrubs *Rubus idaeus* (raspberry), *R. fruticosus* agg. (bramble), *Sambucus nigra* (elder), *Frangula alnus* (alder buckthorn), *Salix* spp. (willows), *Prunus* spp. (cherries) and *Sarothamnus scoparius* (broom); the grasses *Calamagrostis* spp. (small reeds), *Carex* spp. (sedges), *Juncus* spp. (rushes), *Deschampsia caespitosa* (tufted hair-grass) and *Molinia* spp. (purple moor-grass); and the herbs *Impatiens* spp. (balsam), *Senecio* spp. (ragwort), *Dryopteris filix-mas* (male-fern) and *Pteridium aquilinum* (bracken). The most important woody competitors of planted saplings are *Betula* spp., *Populus tremula* (aspen), *Sorbus aucuparia* (rowan) and *Robinia pseudoacacia* (false acacia). The relevance of individual weeds for reforestation in the Czech Republic (according to 79 forest owners, managing about 35 % of forest land) is shown in Figure 1.2.

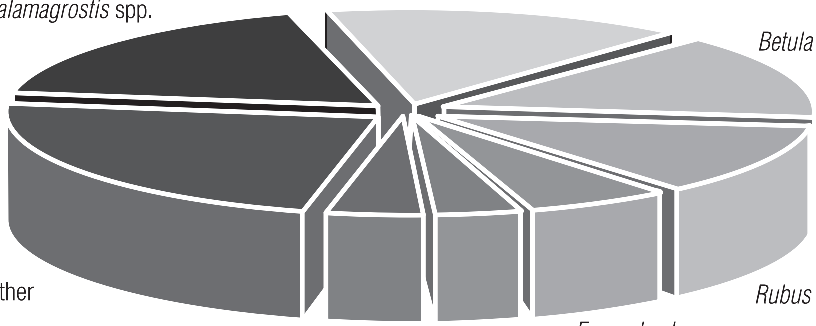

Figure 1.2 I Relevance of individual weeds for reforestation of clear cut areas. Source: *Consumption of chemical preparations for forest protection in 2005* (Janauer *et al.*, 2005).

Treatments and alternatives

Current knowledge

Methods and strategies adopted for managing weeds in Czech woodlands

Silvicultural systems

From the above mentioned overview of silvicultural systems used in our country, it follows that 'high monoculture forest' (artificially regenerated on clearcut areas) still prevails. Tendencies towards increasing the area of 'selection forest' and the area with natural regeneration have been noted in the past but they have not been important until recently. This new approach also includes selection of suitable site conditions and regulation of water and nutrients (Hruska and Cienciala, 2003; Photo 1.1, page 61).

Mechanical methods

Up until now mechanical methods have been in widespread use on 70–80 % of reforested land. Treatment consists of mowing by scythe or grass-hook or by trampling down and in recent years brush saw or cutting by machine (cultivation adaptors with tractors etc.). Most of these treatments are carried out during a growing season. With continuously increasing labour costs, the prospects for weed control by hand (Photo 1.2, page 61) look poor. Cultivation of forest soil before planting could also be included in this type of approach as it is especially effective for afforestation of agricultural land.

Mulches

Woolly biodegradable sheet mulches were used some years ago in the northern area of the Czech Republic and found to be relatively effective and cheap (compared with mechanical or chemical treatments). However, from time to time, the saplings were destroyed by mouse invasion. Bark and other organic mulches are only occasionally used.

Biological weed control

Grazing animals such as cattle and sheep are not practical for controlling weeds due to the risk of planted sapling damage; biological control of weeds is only in the early stages of development.

Herbicides

During recent years herbicides have become the second most common method of weed management. The main herbicides used in Czech woodlands, along with an estimate of annual usage, are given in Tables 1.7 and 1.8.

Table 1.7 I Consumption of most-used herbicides and their percentage of total financial turnover in 2007. Source: *Consumption of chemical preparations for forest protection in 2007* (Janauer *et al*., 2007).

Herbicide	Active ingredients	Consumption (kg or l)	% of total consumption	% of total financial turnover
Casoron G	dichlobenil	21 297	16.1	10.9
Clinic	glyphosate-IPA	4 033	3.0	1.6
Dominator	glyphosate-IPA	3 094	2.3	1.3
Fusilade Forte	fluazifop-P-butyl	1 378	1.0	2.7
Gallant Super	haloxyfop-methyl [*(R)*-isomer]	3 671	2.8	11.1
Garlon 4	triclopyr	1 421	1.1	3.2
Pantera 40 EC	quizalofop-P-tefuryl	728	0.5	1.1
Roundup Forte	glyphosate-IPA, glyphosate	211	0.2	0.3
Roundup (kumul.)	glyphosate-trimesium	35 848	27.1	19.3
Roundup Rapid	hexazione	11 305	8.5	8.7
Touchdown (kumul.)	hexazione	1 023	0.8	0.4
Velpar 5G	hexazione	44 061	33.3	19.0
Velpar 90 WSP	hexazione	3 151	2.4	18.6
Other		1 250	0.9	1.9

Table 1.8 I Weed types – most common control methods adopted and impacts in Czech woodlands. Source: http://www.agromanuaal.cz; List of permitted preparations for forest protection, Ministry of Agriculture, Prague, 2005.

Weeds	Treatment	Effectiveness	Potential environmental impacts
Annual weeds	Herbicides 1	Very effective.	Water and soil contamination, toxicity to plants and animals.
	Mulching	Very effective.	Source of waste.
	Cultivation	Effectiveness varies with weed and site type.	Soil erosion, sediment pollution, disruption to ground-nesting birds.
Perennial weeds	Herbicides 2	Very effective.	Water and soil contamination, toxicity to plants and animals.
	Mulching	Very effective.	Source of waste.
	Cultivation	Effectiveness varies with weed and site type.	Soil erosion, sediment pollution, disruption to ground-nesting birds.
Tree invasion	Herbicides 3	Very effective.	Water and soil contamination, toxicity to plants and animals.
Sprout shoot eradication	Herbicides 4	Very effective; using ‘Hypo-dagger’.	Water and soil contamination,toxicity to plants and animals.
	Mechanical	Effective.	Soil erosion, sediment pollution, disruption to ground-nesting birds.

Herbicides 1 Agil 100 EC (propaquizafop), Cliophar 300 SL (clopyralid), Dominator (glyphosate-IPA), Fusilade Forte 150 EC (fluazifop-P-butyl), Gallant Super (haloxyfop-methyl [*(R)*-isomer]), Garlon 4 EC (triclopyr), Glyfogan 480 SL (glyphosate-IPA), Kerb 50 W (propyzamide), Pantera 40 EC (quizalofop-P-tefuryl), Roundup Biativ (glyphosate-IPA), Roundup Forte (glyphosate), Roundup Klasik (glyphosate-IPA), Roundup Rapid (glyphosate-IPA), Targa Super 5 EC (quizalofop-P-ethyl), Touchdown Quattro (quizalofop-P-tefuryl).

Herbicides 2 Agil 100 EC (propaquizafop), Cliophar 300 SL (clopyralid), Dominator (glyphosate-IPA), Fusilade Forte 150 EC (fluazifop-P-butyl), Garlon 4 EC (triclopyr), Glyfogan 480 SL (glyphosate-IPA), Pantera 40 EC (quizalofop-P-tefuryl), Roundup Biativ (glyphosate-IPA), Roundup Forte (glyphosate), Roundup Klasik (glyphosate-IPA), Roundup Rapid (glyphosate-IPA), Touchdown Quattro (quizalofop-P-tefuryl).

Herbicides 3 Glyfogan 480 SL (glyphosate-IPA), Touchdown Quattro (quizalofop-P-tefuryl).

Herbicides 4 Garlon 4 EC (triclopyr), Glyfogan 480 SL (glyphosate-IPA), Roundup Forte (glyphosate), Roundup Klasik (glyphosate-IPA), Roundup Rapid (glyphosate-IPA), Touchdown Quattro (quizalofop-P-tefuryl).

The development of the most common methods of weed control in the Czech Republic during recent years is given in Figure 1.3.

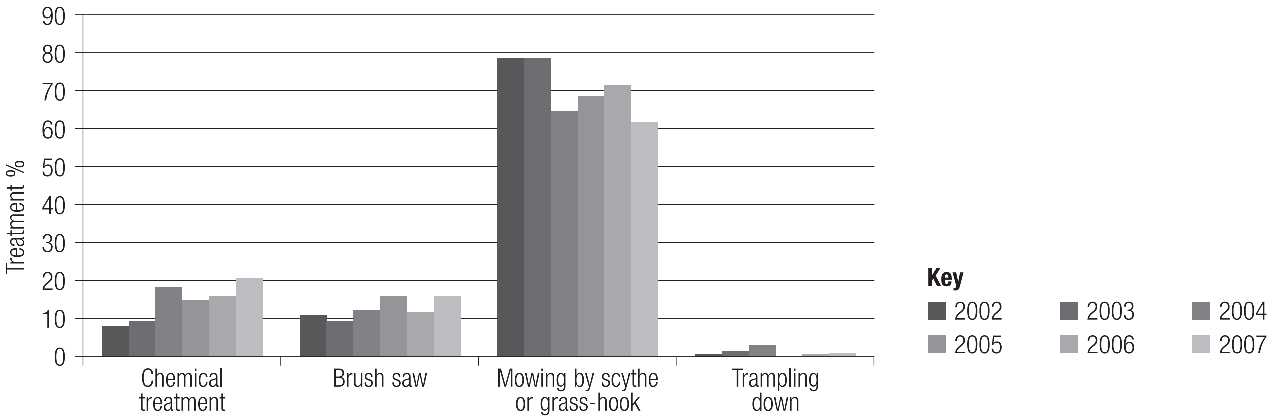

Figure 1.3 | Proportion of the treatments against forest weeds from the whole treated forest area from 2002 to 2007. Source: *Consumption of chemical preparations for forest protection in 2007* (Janauer *et al.*, 2007).

Barriers to adopting alternative methods

The most serious challenge in the Czech Republic is probably not a dramatic decrease in herbicide consumption due to increasing weed control (the area treated by herbicides has not yet reached 20 %; Figure 1.3) but rather that with increases in the costs of labour for mechanical weed control, this may lead to a considerable increase in herbicide use as a more economic alternative.

Ongoing research

Current forestry research is focused mainly on the development of more effective, cheaper and more ecologically friendly procedures for herbicide application. Research into biological control of weeds has not been of interest until recently although there are some exceptions. For example, with long-term work on the control of the invasive alien weed giant hogweed (*Heracleum mantegazzianum*) in the western area of the Czech Republic, reasonable results were obtained with repeated grazing by some breeds of sheep.

Future research needs / potential for European collaboration

As previously mentioned there is no long tradition of research in this branch of science, therefore European collaboration would be particularly welcome.

Barriers to carrying out future research

The factors preventing an increase in research on this topic are not limited to a lack of funding; environmental problems connected with herbicide use have not been clearly explained and communicated in our country and therefore a search for alternatives has not been considered as a priority scientific task to date.

Ecosystem responses

Current knowledge

Effects of weeds on trees

The direct and indirect effects of weeds on young forest trees have been known for a long time in our country. New issues were revealed in connection with increased grass competition related to Norway spruce forest decline in 1980s and 1990s. Continuous increased nitrogen deposition to forest stands also supports weed competition (Fiala *et al.*, 2005).

Nature and magnitudes of effects

The effects of weeds on trees depend on many site environmental factors, not simply on the combination of tree and weed species. Extreme climatic conditions also seem to be very important.

Impact of control methods

Forestry research within the Forestry and Game Management Institute is largely focused on testing new, more effective and more environmentally friendly herbicides, rather than on ecosystem responses.

Ongoing research

Within the framework of COST Action E47, Czech participants of this project are preparing questionnaire research about awareness and perception of problems with vegetation management in forests. This research will involve both public and technical and scientific communities.

Future research needs

There is a need for research into attitudes and perceptions of risk for forest vegetation management practices and possible alternatives.

Barriers to carrying out future research

In addition to funding, researchers interested in participating in such investigations need to be identified in the Czech Republic.

Society and vegetation management

Current knowledge

No official research has been carried out on this topic in the Czech Republic.

Ongoing research

Within the framework of COST Action E47, Czech participants of this project are preparing questionnaire research about awareness and perception of problems with vegetation management in forests. This research will involve both public and technical and scientific communities.

Future research needs

There is a need for research into attitudes and perceptions of risk for forest vegetation management practices and possible alternatives.

Barriers to carrying out future research

In addition to funding, researchers interested in participating in such investigations need to be identified in the Czech Republic.

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2

Denmark

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Country background

History and woodland area

The history of forests in Denmark is relatively short. Most of the country was covered with ice for 110 000 years in the Weischel period and the land was only freed about 12 000 years ago. Around 8300–7000 BC the country was covered with forest of predominantly birch (*Betula pubescens* and *B. pendula*), aspen (*Populus tremula*), rowan (*Sorbus aucuparia*) and Scots pine (*Pinus sylvestris*). Around 3000 BC drastic losses occurred in forest cover when Stone Age farmers and later Bronze Age farmers changed the forest through exploitation, extensive grazing and clearing for pastures and fields. By 1700 AD forest cover had declined to 2–3 %, and several forest protection legislations were unsuccessfully enforced in the 18th century. In 1805 a desperate lack of wood products and increasing problems with soil erosion and sand drift finally lead to forest protection legislation (Fredskovsforordningen), which became an important milestone and halted centuries of unsustainable forest management. Between 50 and 70 % of the remaining forests were fenced and protected against grazing and uncontrolled logging.

Since 1805 the main increase in forest cover has been based on plantations of exotic conifers such as Norway spruce (*Picea abies*), Sitka spruce (*Picea sitchensis*), Japanese larch (*Larix kaempferi*), Douglas-fir (*Pseudotsuga menziesii*), silver fir (*Abies alba*) and pines, e.g. *Pinus sylvestris* and *P. mugo*. From the late 1860s patriotic interest boosted reclamation of bare heathland and other low productive areas in Denmark over the following century. In western Jutland the vast areas of heathland were replaced with conifer plantations and farmland (Madsen *et al.*, 2005). As growing conditions were extremely poor on these heathlands, only the most tolerant conifers like mountain pine and Norway spruce had a fair chance of establishing as first generation plantations.

No virgin forest remains and thus there is little knowledge about the structure of natural forest in Denmark. The nearest examples of natural forest are a few patches that have been left unmanaged for some decades or in a few cases more than a century (Larsen, 2005; Heilmann-Clausen *et al.*, 2007).

The 2002–2006 forest cover is 534 488 ha or approximately 12 % of the area of Denmark (Table 2.1); 32 900 ha or 6 % of the forested area is under regeneration either artificially with planting or by natural regeneration. Due to a major transition towards nature-based (close-to-nature) forest management, it is expected that artificial regeneration will be used to a lesser extent in the future. However, storms like those in 1999 and 2005 may temporarily increase the areas that are artificially regenerated.

Nordmann fir (*Abies nordmanniana*), which is mostly harvested within 10 years for Christmas trees, covers 19 % of the regenerated area followed by Oak (15 %) and beech (14 %). In total broadleaves covers 49 % of the regenerated area (Skov and Landskab *et al.*, 2008).

Land use	Area (ha)	Percentage (%)
Agriculture and fallow	2 903 855	67.4
Forest	534 488	12.4
Other tree covered areas	41 079	1.0
Lakes, streams	67 059	1.6
Other purposes	1 176 637	17.6
Total	**4 309 831**	**100.0**

Table 2.1 | Land use in Denmark in 2002–2006 (Danmarks Statistik, 2008, Skov and Landskab *et al.*, 2008).

The afforestation programme

In 1989 the Danish Parliament decided that the forest area should be doubled within 80–100 years, giving an average annual afforestation of 5 000 ha. An overall goal is that 50 % of the afforestation takes place on privately owned land and 50 % on public land. Originally, the purpose of the afforestation programme was to increase the national self-sufficiency in wood and to reduce the vast agricultural overproduction by afforesting marginal lands. In later years the scope has been broadened to comprise recreational values, carbon sequestration, ground water protection and biodiversity (Miljøministeriet, 2002).

Private landowners may get subsidies to support afforestation depending on the location of their land in the landscape, the tree species and the regeneration methods applied. Afforestation with broadleaves and without using pesticides attracts the highest subsidies (Skov- og Naturstyrelsen, 2006; Madsen *et al.*, 2005). Public landowners (except the state) may receive grants from the EU (Skov- og Naturstyrelsen, 2005).

The afforestation aims of private landowners typically include inherent satisfaction of ownership, recreation, hunting and watching wildlife, and increased property value. Wood production is not really a driving force but subsidy regulations and silvicultural traditions ensure that new forests are well stocked. In addition, landowners also want their new forests to develop into high forest as quickly as possible, which creates an important role for the fast growing nurse species.

From 1997 to 2006 approximately 1100 ha was planted annually on public land or on private land with subsidies. Additionally, unsubsidized afforestation, which for the period 1989 to 1998 was estimated to cover 62 % of the total afforestation (Kirkebæk *et al.*, 2000). Most of the unsubsidized afforestation is, however, Christmas tree plantings, of which a large proportion will never be allowed to develop into high forest. There are numerous restrictions and incentives involved in governmentally subsidized afforestation (Madsen *et al.*, 2005). The most important is that the forest will develop into a high forest and that forestry becomes the only legal land use for the future.

Topography and climate

Denmark consists of 1419 islands (Kort og Matrikelstyrelsen, 2008), of which 72 are inhabited (Danmarks Statitik, 2008), and a peninsular connected with continental Europe. The average altitude is 31 metres above sea level, ranging from -7.5 to 173 m asl (Kort og Matrikelstyrelsen, 2008).

The Danish climate is greatly affected by the location between the North Sea and the Baltic Sea. Average (1961–1990) annual temperature is 7.7 °C. Average temperatures in January and July are respectively 0.0 °C and 15.6 °C (Danish Meteorological Institute, 2008). Average precipitation (1961–1990) is 712 mm ranging from 584 mm in the western part of the main island Sealand to 823 mm in the southwestern part of the country (Danish Meteorological Institute, 2008). Prevailing winds are from the west with an annual average wind speed of 5.8 m s^{-1}.

Species composition in forests

Species coverage is shown in Table 2.2.

Species	Area 1990 (000 ha)	Area 2000 (000 ha)	Area 2006 (000 ha)
Forest area	445	486	534
Beech *(Fagus sylvatica)*	72	80	69
Oak *(Quercus robur, Q. petrea)*	30	43	46
Ash *(Fraxinus excelsior)*	10	13	19
Sycamore *(Acer pseudoplatanus)*	8	9	17
Other broadleaves	23	30	73
Norway spruce *(Picea abies)*	135	132	102
Sitka spruce *(Picea sitchensis)*	35	34	34
Noble fir *(Abies procera)*	7	12	10
Nordmann fir *(Abies nordmanniana)*	12	28	21
Other true firs	15	15	14
Other conifers	64	72	37

Table 2.2 I Forest area and species coverage in 1990, 2000 and 2006 (Skov and Landskab *et al.*, 2008). Inventories for 1990 and 2000 are based on questionnaire surveys. The 2006 inventory is based on random samples. Developments in forest cover and species coverage may be caused by real changes and/or by changes in methodology.

Standing volume and growth

The standing volume in Denmark's forests is 106.3 million m^3 or 199 m^3 ha^{-1}. The annual volume increment is estimated to be 10 m^3 ha^{-1} yr^{-1} or 5454 m^3 yr^{-1}, with broadleaved species yielding 8 m^3 ha^{-1} yr^{-1} and coniferous species yielding 12 m^3 ha^{-1} yr^{-1} (Skov and Landskab *et al.*, 2008).

Forest ownership

As shown in Table 2.3, around 30 % of the forest area is owned by the state or other public authorities; the rest belongs to private owners, companies and foundations.

Land use	Area (ha)	Percentage (%)
Private and companies	344 157	64.4
Foundations	23 014	4.3
Forest and Nature Agency (state)	123 597	23.1
Other state owned	7 562	1.4
Counties and municipalities	28 941	5.3
Unknown owner	7 218	1.4

Table 2.3 I Forest ownership in Denmark in 2002–2006 (Skov and Landskab *et al.*, 2008). Rounding errors cover the balance to 100 % in the percentage column.

The structure of ownership plays an important role in relation to forest management practices. The forests in private ownership are spread over 24 874 properties; 57 % of these owners have education or training in forestry or agriculture (Boon, 2003); 58 % of privately owned forest properties and 98 % of the total number of forest properties are smaller than 50 ha (Larsen and Johansen, 2002). Danish forestry can therefore be characterized as small scale with a wide range of management objectives.

Woodlands owned by the Danish state, municipalities, the church and most private owners are designated as permanent forest land, and thus protected, giving a total protected area of 85 %. Some exceptions exist allowing, for example, the production of Christmas trees on a maximum of 10 % of the area in permanent forest lands.

Certification

Two of the major certification schemes are implemented in Denmark. Four estates covering 189 643 ha are certified according to the FSC scheme (FSC, 2008: www.fsc.org) while forests certified according to the PEFC cover 206 357 ha (PEFC, 2008: www.pefc.dk). Forest owned by the Forest and Nature Agency along with other forest estates are certified according to both FSC and PEFC. There is thus a huge overlap in the above figures.

Certification according to FSC or PEFC imposes only minor restrictions on the range of pesticides available, but usage of pesticides must always be justified by external experts. Steps need to be taken to reduce and eventually exclude the consumption (PEFC, 2007; FSC, 2004).

Silvicultural systems and silvicultural history

Historically, clearcutting has been the most widespread silvicultural system in plantation forests. This is partly an outcome of the short 200-year history of sustainable forest management. Conifer plantations in particular, which cover about two-thirds of the forest land, have always been subjected to a plantation management system. In the windy Atlantic climate of Denmark most of the conifers are severely prone to windthrow, particularly where shelterwood or irregular shelterwood systems have been introduced in stands taller than approximately 14 m. The later or more intensive the thinning the more it destabilizes the stand. Larch, red cedar (*Thuja plicata*), Douglas-fir (> 70 years old) and some other North American conifer species are relatively resistant to windthrow. It should be stressed that all species at almost all ages can be affected by windthrow – it is just a matter of windspeed.

In practical terms, clearcutting is a challenging system for regeneration of particularly shade tolerant species like beech, with weed competition, rodent damage and frost being the most severe constraints. Throughout the 1960s, 1970s and 1980s vegetation management was mainly based on herbicide use. Before herbicides became common a range of silvicultural techniques such as shelterwoods, strip systems, nurse crops, e.g. larch, birch, black alder (*Alnus glutinosa*), grey alder (*Alnus incana*), and intensive weeding (mowing or soil preparation) were used. Shelterwood and strip systems are problematic in coniferous stands as such heavy thinnings can cause severe destabilization.

The clearcutting system has been widely used for broadleaves, too. They offer more silvicultural alternatives because of their better stability, due to greater resistance to windthrow and drought/dieback than conifers. Beech is the most important broadleaved species, and beech silviculture often involves the uniform shelterwood system and natural regeneration based on one seed mast and supported by soil preparation (Photo 2.1, page 61). If ash (*Fraxinus excelsior*) and sycamore (*Acer pseudoplatanus*) seed sources are present they often regenerate vigorously and mix with the beech. Sycamore is particularly competitive and will often out-compete the beech.

Bare-rooted seedlings are presently the most common stock type: usually 2–0 or 2–1 undercut seedlings (two to three years in the nursery). Traditionally, stock density is high: commonly 2500–3500 conifer seedlings ha^{-1} and 4000–6000 broadleaved seedlings ha^{-1}. Some species with pioneering characteristics, including broadleaves like ash and sycamore, may be planted at low densities (2000 ha^{-1}).

As in many other countries the so-called nature-based silviculture has gained a lot of popularity during the past 15 years (Hahn *et al.*, 2005). In 2002 the Danish Forest and Nature Agency (DFNA, government forests) decided to implement nature-based silviculture in the management of government forests. It is also being increasingly used in privately owned forests. Nature-based silviculture is seen as a promising approach towards fulfilling the multipurpose goals of sustainable forest management, including commercial, social, environmental, as well as personal goals and preferences for the many private owners.

Nature-based silviculture goes back to Swiss and German forestry movements in the late 19th and early 20th century. In the 1920s it was called the ‘Daurwald-movement’ (continuous cover) and it had strong relations to silvicultural systems such as single tree selection, group selection and irregular shelterwood (Matthews, 1997). There is no short and simple definition of nature-based silviculture.

In Denmark the DFNA supports the implementation of nature-based silviculture with a 13-point operational guideline for government forests, and they want to see this being introduced into as much of the privately owned forest as possible. The overall approach is to take advantage of and mimic the natural processes and patterns of natural forest ecosystems. This was described as early as 1781 by The Royal Forest Decree: ‘… to follow and support Nature in her performance’. Yet numerous questions remain unanswered on how to match landowner’s management goals with a proper choice of silvicultural system. Today, both the variety of goals and silvicultural systems are greater than ever and much of this may change within a tree generation.

Generally, present-day silviculture is taking a nature-based silviculture approach with less or no use of herbicides (supported by higher subsidies for non-pesticide regenerations), growing more broadleaves and better site-adapted species, i.e. a more continuous cover forestry approach. Vegetation management within this context is primarily a matter of maintaining the canopy density, and managing the light and soil moisture levels within a reasonable range to keep the regeneration competitive against ground vegetation.

Clearcuts are still common. Conifer plantations do not offer many alternatives unless their managers or owners are willing to accept a considerable windthrow risk. Nurse crops appear to be increasingly used to counteract the reduced use of herbicides and pesticides in general, although no data is yet available to confirm this.

Herbicide use

The overall pesticide use in Denmark is registered by the Danish EPA. The annual accounts are based on sales figures reported by holders of the certificate of approval to the Ministry of Environment. A separate account is made on the use of pesticides in agriculture but there are no statistics on the specific use in forestry and Christmas tree production. A survey of pesticide use in 1995–1996 showed that 90 % of sales were to agriculture, 4.6 % to horticulture and fruit production, 3.5 % to private gardens and less than 1 % to forestry and the public sector (Miljøstyrelsen, 1997). Table 2.4 shows the use of pesticide groups for agricultural and other purposes, where forestry is part of ‘other purposes’.

Pesticide sales (2006)	Agriculture (tonnes a.i.)	Other purposes (tonnes a.i.)	Total (tonnes a.i.)
Herbicides	2479	171	2650
Fungicides	536	124	660
Insecticides	57	43	100
Growth regulators	140	22	162
Total	**3212**	**360**	**3572**

Table 2.4 | Pesticide sales (metric tonnes of active ingredient) in 2006 for agricultural and other purposes (Miljøstyrelsen, 2007).

Policy drivers and herbicide regulations

The present regulation of the use of pesticides in Denmark dates back to 1980 with many changes since. EU directive 91/414 on the marketing and sale of pesticides was adopted into Danish law in 1993, and the majority of recent statutory orders are more or less direct transcripts of the EU directive.

Several action plans on the reduction of pesticide use have been launched. In 1986 the Minister for the Environment presented a plan for a 25 % reduction by 1990 (relative to 1981–1985 amounts), followed by an additional 25 % reduction by 1997. A progress report from 1997 showed that the quantity sold was almost halved, whereas the treatment frequency had not been reduced (treatment frequency expresses the number of times the total arable land in Denmark can on average be treated with the sold quantities of pesticides when used in normal dosages).

In 1997 a committee was formed to evaluate the consequences of phasing out pesticide use in agriculture, horticulture and forestry; their report was published in 1999. Based on the committee's recommendations, Pesticide Action Plan II was presented in 2000 (Miljø-og Energiministeriet, 2000) with new reduction targets bringing the treatment frequency down to 2.0 before the end of 2002. The target had almost been met with a treatment frequency in 2002 of 2.04 when the third action plan on pesticide use was presented in 2003; this has a new target of 1.7 before the end of 2009 (Miljøministeriet, 2003).

The grant system for private forest owners includes incentives to avoid the use of pesticides. For afforestation on private agricultural land, the use of non-chemical afforestation methods attracts an additional 3 000 DKR (€400) ha^{-1} (Skov-og Naturstyrelsen, 2006). In addition 6 000 DKR (€800) ha^{-1} can be granted for restocking after the wind throw of 2005, without the use of pesticides and deep ploughing (Stormrådet, 2005).

Pesticide use in publicly owned forests

In 1996 the Forest and Nature Agency that manages 23 % of the Danish forest area presented a strategy for the use of pesticides in their own forests (Skov-og Naturstyrelsen, 1996). The strategy imposed (from 1 January 1997) a halt to the use of soil disinfection, growth regulators, herbicides except glyphosate, insecticides except in Christmas tree plantations, nurseries and against *Hylobius abietis*, and fungicides except in nurseries.

This strategy was followed by a voluntary agreement in 1998 between the Ministry of the Environment, the counties and the municipalities to discontinue the use of herbicides unless safety precautions required it. Pesticide consumption had to be phased out before 2003 and from 1 January 2003 pesticide was excluded from publicly owned forest areas.

Several surveys have been made on public sector consumption of pesticides before and after implementation of the various action plans. Based on three questionnaire surveys, Kristoffersen and Rytter (2003) report that the annual pesticide consumption in state owned forests has declined from 4182 kg a.i. in 1995 to 427 kg a.i. in 2002. The corresponding figures for forests owned by municipalities are 1060 kg a.i. in 1995 to 175 kg a.i. in 2002; in general an 80–90 % decrease from 1995 to 2002.

Problematic weeds in forestry and Christmas tree production

The weed species listed below are commonly experienced as most problematic (Rubow, 2002).

Grasses and other monocotyledonous species

As weeds this group shares some of the same characteristics in terms of competing for water and nutrients, and promoting late spring frost damage and rodent habitat. Main species are: Chee reedgrass (*Calamagrostis epigeios*), tufted hairgrass (*Deschampsia cespitosa*), wavy hairgrass (*Deschampsia flexuosa*), orchardgrass (*Dactylis glomerata*), annual bluegrass (*Poa annum*), perennial ryegrass (*Lolium perenne*), quackgrass (*Elymus repens*) and common rush (*Juncus effuses*).

Dicotyledonous species

The main dicotyledonous species (herbs) are: stinging nettle (*Urtica dioeca*), curly dock (*Rumex crispus*), prostrate knotweed (*Polygonum aviculare*), lambsquarters (*Chenopodium album*), wild mustard (*Sinapis arvenis*), creeping yellowcress (*Rorippa silvestris*), field bindweed (*Convolvulus arvensis*), American red raspberry (*Rubus idaeus*), shrubby blackberry (*Rubus fruticosus*), geranium (*Geranium spp.*), fireweed (*Chamaenerion angustifolium*), fringed willowherb (*Epilobium ciliatum*), cleavers (*Galium aparine*), field sowthistle (*Sonchus arvensis*), bull thistle (*Cirsium vulgare*), Canada thistle (*Cirsium arvense*), common wormwood (*Artemisia vulgaris*), Canadian horseweed (*Conyza canadensis*) and scentless false mayweed (*Tripleurospermum inodorum*). These species mainly compete for light or impose physical damage, particularly when they collapse in winter.

Pteridophytes

Western bracken fern (*Pteridium aquilinum*) and field horsetail (*Equisetum arvense*) appear to be the most problematic.

Woody species

A range of woody species may be experienced as problematic, especially in conifer regeneration. Species like birch (*Betula* spp.), black cherry (*Prunus serotina*), sycamore (*Acer pseudoplatanus*) and Scotch broom (*Cytisus scoparius*) are often managed to reduce shade and physical damage to the planted stock.

Treatments and alternatives

In most agricultural and forestry practices there is a competitive interaction between the crop and other species. Forest vegetation management is about supporting crop survival and growth by shifting the competitive interaction in favour of the crop. This can be done by reducing the competitive strength of undesired species or enhancing the competitive strength of crop species, or both. There is no unique definition of 'weed', but it is commonly considered to be an undesirable plant species imposing competition on crop species. Competition may be defined as (Henriksen, 1988):

- Passive – competition for water, light and/or nutrients.
- Indirect – weeds encourage the appearance/occurrence of other harmful organisms or incidents, e.g. mice or spring frost.
- Active – weeds inflict physical damage or growth retardation to the crop, e.g. by allelopathy or Thigmomorphogenesis.

Applied strategies for managing weeds in Danish woodlands and Christmas tree plantations

No official statistics are available yet on the extent of vegetation management in Danish woodlands. A survey among major forest owners and management companies shows that vegetation management is carried out mainly in afforestation on richer soils and in forest regeneration with broadleaved species on richer soils. In these situations 50–80 % of the regenerated or afforested area is treated in a period after planting. On lighter soils, post-planting vegetation management may be rare but pre-planting vegetation management is very common with probably 90–100 % of the area being treated before planting. The incentives in grant systems to avoid pesticides seem to be efficient: it is estimated that in close to 100 % of all financially supported afforestation sites vegetation is managed without pesticides. The equivalent estimate for broadleaf regeneration after windthrow is 70–90 %. In state-owned forests vegetation management is generally declining due to a transition to nature-based forest management practices.

Herbicides used in Danish forestry and Christmas tree production

Herbicides are the most commonly used method of vegetation management in Christmas tree plantations (Photo 2.2, page 62); estimates show that on 70 % of the area weeds are managed by herbicides only, with most of the remaining area being managed with a combination of herbicides, mechanical methods or animals (Bichel-udvalget, 1999). Only around 1.5 % (350–400 ha) of the Christmas tree area is managed according to an organic certification scheme (Bentsen *et al.*, 2004). The main herbicides used in Danish Christmas tree plantations and forests are given in Table 2.5. Glyphosate is believed to be the most used in quantity and frequency in both Christmas tree production and forestry.

Active ingredient	Product	Use	Approval
Amidosulfuron	Gratil, Eagle	Christmas trees	Off label
Clopyralid	Matrigon	Christmas trees and forests	Ordinary
Diflufenican	Zeppelin	Christmas trees and forests	Ordinary
Diuron	Karmex	Christmas trees and forests	Ordinary
Florasulam	Primus	Christmas trees	Off label
Fluazifop-P-Butyl	Fusilade Max	Christmas trees and forests	Ordinary
Foramsulfuron/Iodosulfuron	Logo	Christmas trees	Ordinary
Glyphosate	Roundup	Christmas trees and forests	Ordinary
MCPA	Metaxon	Christmas trees and forests	Off label
Propyzamide	Kerb 500 SC	Christmas trees and forests	Ordinary
Rimsulfuron	Titus	Christmas trees	Off label
Prosulfocarp	Boxer EC	Christmas trees	Off label
Clethodim	Select 240 EC	Forests	Ordinary

Table 2.5 I Herbicides used in forestry and Christmas tree production (Bentsen, 2008).

Mechanical methods

As pesticide use is prohibited on more than a quarter of the forest area mechanical methods are regularly used.

Cultivation

On intermediate and light soils, mainly in the central and western part of Denmark, pre-planting vegetation management is an integral part of site preparation. Tractor-drawn tools such as trenchers, rotators or mill harrows are commonly used. Some research has been done to compare different site preparation methods. Soil augers and excavators showed superior performance in terms of seedling survival compared to tractor-drawn tools (Suadicani, 2003). In general augers and excavators are considered too expensive in many situations and the former are mainly used in regenerating small patches and in shelterwood systems.

Cutting

On fertile soils cutting is commonly used for post-planting vegetation management. Two-wheeled tractors (Photo 2.3, page 62) are often used to carry cutting tools as they are flexible and relatively cheap. In locations exposed to spring frost cutting can be problematic as it promotes a shift in species composition towards grasses (Bentsen, 2003).

Mulches

Some research has been done on mulches of different materials (Kjærbølling, 1997; Sønnichsen *et al.*, 2001) with differing results. In practice mulches are not in large-scale use due to the relatively high cost of applying and maintaining them.

Biological weed control

World wide, examples of successful biological weed control are numerous. Most are typical classical biological control such as the introduction of a biological agent to control an introduced plant species that has developed into an alien invasive weed. In Europe there are no examples of classical biological weed control to date. However, many of the more problematic weed species mentioned are considered invasive weeds and could be candidates for classical biological weed control, e.g. *Epilobium ciliatum*, *Conyza canadensis*, *Pteridium aquilinum*. A biological control method was recently developed for *P. aquilinum*, using a noctuid larvae from South Africa as the control agent. However a release experiment was halted due to the risk of negative influence on other (redlisted) organisms in the release area (Matthew Cock, CABI, personal communication). Proposals were made for using native herbivorous insects – the weevil *Ceutorhynchus litura* and the butterfly *Vanessa cardui* – for control of *Cirsium arvense* but the project was never funded. One example of implemented biological control of weeds in Denmark is sheep grazing in Christmas tree plantations. Other grazing animals have also been used (geese, pigs, ostriches) but sheep are the most popular (Theilby, 1996). It is worth noting that afforestation itself could be used as a method for control of invasive weeds, for example beech trees can outshade giant hogweed, *Heracleum mantegazzinum*, which is recognized as one of the most pernicious invasive weeds in Europe (Ravn *et al.*, 2007).

Barriers to adopting alternative methods

Alternative vegetation control methods are generally adopted in many parts of Danish forestry, but pesticide use still prevails in certain areas. Christmas trees are probably the most herbicide intensive crop, but herbicides are also commonly used in afforestation and forest regeneration on privately owned forest land at rich sites.

Cost in combination with silvicultural tradition is considered a major barrier to the adoption of alternative vegetation control methods. If forest management aims at the same productivity within the same timeframe as achievable by using pesticides, then alternative methods will usually be more costly – particularly in intensively managed crops like Christmas tree plantations. For forest regeneration and afforestation some alternatives like using nurse crops seem to be competitive to using pesticides both regarding productivity and profitability. The documentation required for approval and registration presents a major obstacle to the use of a biological control agent (pathogen or herbivorous insect).

Ongoing research

National funding for research in forest vegetation management is very limited. From 2000 to 2005 two primary sources of funding for applied research in forest management allocated only a small percentage of their funds to vegetation management; 6 % of 20 219 428 DKK (€2.7 million) was allocated to these projects addressing forest vegetation management (Produktudviklingsordningen for Skovbruget og Træindustrien, 2001, 2002, 2003, 2005, 2006). Current research focuses on developing non-chemical vegetation management practices, (re)introducing cover crops, nurse trees, and focusing on longer timescales. Improving the competitiveness of seedlings is also a research issue.

For Christmas tree research only two projects addressing vegetation management were funded from 2000 to 2005 from a total research pool of 15 900 074 DKK (€2.1 million) (Produktionsafgiftsfonden for Juletræer og Pyntegrønt, 2001, 2002, 2004, 2005, 2006). Research focuses on testing new herbicides for use in Nordmann and Noble fir plantations. Research in forest vegetation management may be funded from other sources but no official records exist.

Future research needs

A long-term research challenge is to understand the fundamental mechanisms and interactions of disturbance as well as competition and use this in designing appropriate vegetation control methods. On the road to that understanding forest management still needs a range of tools to deal with undesired vegetation.

Recommended future research includes:

- Alternative weeding methods and vegetation mangament approaches and their impacts on crop and environment: nurse crops, cover crops and different mechanical weeding and site preparation methods.
- Biocontrol of selected target weeds.
- Development of selective weed control depending on how aggressively weed species behave.
- New herbicides and application technologies – optimizing efficiency as well as minimizing dosage and side-effects.

Barriers to carrying out future research

Lack of funding is a major obstacle to carrying out research. The forestry sector in Denmark is economically weak and does not push very hard for developments in new vegetation control technologies.

Ecosystem responses

Current knowledge

Effects of vegetation management on soil, water and flora

An investigation of the flora and fauna in conventional and organic Christmas tree plantations showed significant differences in the flora between the two management systems. There were more perennial plants in the organic areas and more annual plants in the conventionally managed (herbicide) areas; and the Ellenberg index showed significantly lower pH and nitrogen affinity in plants in organic areas compared to conventional (Ravn and Riis-Nielsen, 2006).

Effects of vegetation management on fauna

An investigation of the effects of different weed management methods used in reforestation and afforestation showed that mechanical tillage, ploughing etc. has a dramatic effect on ground beetle fauna and on the micro-arthropod fauna in the soil, e.g. collembolas and mites reacted very negatively to intensive soil treatment (Pedersen *et al.*, 2000; Ravn, 2005). The soil fauna fulfils an important function in keeping the structure of the soil in a fertile condition.

It is well documented that comprehensive soil treatment, which provides a planting area with pure mineral soil before planting coniferous trees, will help to prevent damage by the large pine weevil (*Hylobius abietis*) feeding on the root collar of new plants (Ravn *et al.*, 2006).

Future research needs

There is much focus on forests as a means of preserving groundwater quality as nitrate leaching and pesticide use in general is lower in forests than in agriculture. Scientific results have shown that the choice of vegetation management method has a major impact on nitrate leaching. Some mechanical methods lead to higher leaching than herbicide use (Pedersen *et al.*, 2002). Also deep ploughing, which is commonly used as soil preparation in afforestation on lighter soils, leads to higher leaching than traditional agricultural ploughing (Gundersen *et al.*, 2001). There is an obvious trade-off between different impacts on ecosystems from different methods of vegetation management that needs research focus. The aim must be to reduce the total impact from vegetation management on ecosystems and not only to substitute one impact with a different impact.

Barriers to carrying out future research

No information is available at present.

Society and vegetation management

Current knowledge

Public opinion on forest vegetation management was studied in 1977 and 1994 (Jensen, 1999). Based on verbal discussion/questionnaires manual weeding (using scythes) was found to be relatively acceptable (ranked 22 and 26 out of 100 in 1977 and 1994 respectively). Weeding with herbicides was ranked lowest in both 1977 and 1994. Fencing and fertilization of forest stands and herbicide use were considered more unpopular in 1994 than in 1977 as its ranking dropped from 59 out of 100 in 1997 to 69 out of 100 in 1994.

A survey on private forest owners' use of pesticides showed that less than one-third chose to use them, indicating widespread decision against pesticide use also within the forestry community (Boon, 2003). Pesticide use appears to be largely related to the production of Christmas trees.

Much research is carried out to determine public opinion on pesticide use and vegetation management in general, both on people's preferences and on their willingness to pay, but very little of the research is targeted towards addressing specific operations in forestry and Christmas tree production.

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3

Finland

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Country background

History and forest policy

In the 19th century Finland's forest resources were dwindling at an alarming rate, due to selective fellings and the gathering of firewood. Before this period forest destruction had been caused by shifting cultivation, forest pasturing and the manufacturing of tar and charcoal. In 1886 a new Forest Act was passed, prohibiting the destruction of forests and striving to safeguard their regeneration after felling. After Finland's independence in 1917 significant reforms in forest policy were passed in the 1920s.

During the 1990s, Finnish forest policy was thoroughly reformed. The concept of sustainable forestry was redefined and the sustainability requirements for ecology, social forestry and timber production were given equal importance. The main elements of Finnish forest policy are defined in the National Forest Programme (NFP) 2015 (Ministry of Agriculture and Forestry, 2008), while the regional objectives are published in the Regional Forest Programmes. The NFP aims to ensure forest-based work and livelihoods, biodiversity and vitality of forests, and recreational opportunities for everyone.

The Finnish sawmilling industry began developing in the middle of the 19th century, when pulp and paper mills were also first established. In the 1950s, the paper and sawmilling sectors still accounted for 80 % of the country's export earnings. Even though the structure of the economy and industry in Finland has diversified since then the forest sector's importance is still relatively greater in Finland than elsewhere in Europe. The forest industry's share of national industrial production is about a fifth and of export earnings a quarter.

Topography and climate

Most of Finland belongs to the boreal coniferous forest zone. The main factor influencing Finland's climate is its location between the 60th and 70th northern parallels. A quarter of Finland's total area lies north of the Arctic Circle. The Finnish landscape is mostly flat with few hills, dominated by thousands of lakes, especially in central and eastern parts of the country.

Climate shows both maritime and continental characteristics, depending on the direction of air flow. Mean temperatures for January and July are much higher in the south of the country (Helsinki: January -4.2 °C, mean 30-year range -1.7 to -6.9; July 17.2 °C, range 13.7 to 20.9) than in the north, above the Arctic Circle (Sodankylä: January -14.2 °C, 30-year range -9.5 to -19.6; July 14.3 °C, range 6.4 to 16.6). Coldest temperatures recorded in the Helsinki area are -34 °C and in Sodankylä -49.5 °C. Annual precipitation in the Helsinki area is 640 mm and 500 mm in Sodankylä, above the Arctic Circle. Approximately half of the precipitation falls as snow. Mean of growing degree days is above 1300 in southern Finland, close to 900 in the Arctic Circle and close to 500 in northern Lapland.

Woodland area

Finland is the most extensively forested country in Europe (Photo 3.1, page 62). Finland's forests are northern boreal. Forestry land occupies 26 million ha or 86 % of the land area of Finland. This is divided into forest land (66 % of land area), scrub land and waste land (Table 3.1). All forest land and most of the scrub land meet FAO's definition of forest land. Mires account for 34 % of forestry land. A total of 4.8 million ha of land has restrictions on wood protection. The area of strictly protected forest land in Finland is the highest in Europe, totalling 1.5 million ha (forest land, scrub land) and covering 6.6 % of the land area (Parviainen *et al.*, 2000).

Land use	Area (ha)	Percentage (%)
Forest land	20 164 000	66.3
Scrub land	2 769 000	9.1
Waste land	3 142 000	10.3
Other forestry land	204 000	0.7
Total forestry land	**26 280 000**	**86.4**
Agricultural land	2 761 000	9.1
Built-up areas, other	1 373 000	4.5
Total land area	30 414 000	100

Note: On forest land the stand capability of producing volume increment is 1.0 m^3 ha^{-1} yr^{-1} or more, on scrub land 0.1 m^3 ha^{-1} yr^{-1} or more, and less on waste land.

Table 3.1 | Land use in Finland. Source: Peltola, 2007.

Species composition and growing stock

Of the growing stock volume on forest and scrub land (2189 million m^3), 50.4 % consists of Scots pine (*Pinus sylvestris*), 30.1 % of Norway spruce *(Picea abies)*, 16.2 % of birch (*Betula pendula* and *B. pubescens*) and 3.5 % of other broadleaves (Peltola, 2007). The annual increment of the growing stock in Finland is 98.5 million m^3; this is an increase of 72 % since the 1960s. The annual increment of the growing stock on forest and scrub land in Finland is 4.3 m^3 ha^{-1} yr^{-1}. Annual growth is much higher in southern Finland (6.0 m^3 ha^{-1} yr^{-1}) than in northern Finland (2.5 m^3 ha^{-1} yr^{-1}).

Ownership and subsidy regime

Of the total forested land, 52 % belongs to non-industrial, private forest owners, 35 % to the state, 8 % to companies and 5 % to municipalities, parishes etc. (Peltola, 2007). State-owned forests are mainly situated in northern Finland. Thus the state forest's share of the total growing stock volume (2189 million m^3) is only 20 %. There are almost one million private forest owners in Finland (almost 20 % of the population) if all those who jointly own forest holdings are included.

According to the 1996 Act and Degree on the Financing of Sustainable Forestry, in order to ensure the sustainability of timber production and vitality of forests, funds may be granted for the following work promoting the management and use of forests:

1. forest regeneration
2. prescribed burning
3. tending of young stands
4. harvesting of energy wood
5. remedial fertilization
6. ditch cleaning and supplementary ditching
7. forest road construction.

For forest regeneration, subsidies are granted when the regeneration costs compared with cutting incomes are low. For example, if the stump price of a stand in southern Finland is less than €1820 ha^{-1}, the subsidy for the regeneration work is 20 % of the costs.

Silvicultural systems

In 2006 the annual felled area in Finland was 619 000 ha: the clearfelled area was 145 000 ha and the balance was mainly thinnings. Average annual planted or seeded regeneration area in the years 1970–2006 was 124 600 ha. The highest regeneration area was recorded in 1982 when 151 000 ha of forests were either planted or seeded. In 2006 around 119 000 ha of forest was regenerated artificially. During 2006 before planting or seeding, 62 600 ha of the regeneration area were cleared of brush and soil was prepared on 122 300 ha (scarification, harrowing, mounding, ploughing); 74 % of the artificially regenerated area (119 000 ha) was planted and 26 % seeded. Altogether 168 067 000 seedlings were planted in Finnish forests in 2006: 69 % spruce, 28 % pine and 2.6 % birch. A total of 8620 kg of seeds were used in direct seeding.

After regeneration grass suppression was carried out on 6700 ha at a total cost of €823 000 (Peltola, 2007). Most of this was done by mechanical or manual methods with chemical grass suppression on only 1650 ha. Tending of young stands (mechanical clearing of non-herbaceous, woody vegetation) was done on 140 000 ha at a total cost of €47 869 000.

According to the statistical yearbook of forestry the average cost for clearing a regeneration area in private forests was €138 ha^{-1} in 2006 (Peltola, 2007). The cost of soil preparation depended on the method selected (scarification: €239 ha^{-1}, harrowing €152 ha^{-1}, mounding €270 ha^{-1}). Seeding was much cheaper (€182 ha^{-1}) than planting (€597 ha^{-1}). Thus for a site that was cleared after clearcutting then mounded and planted the average cost would be €1000 ha^{-1}.

Herbicide use and comparisons

The use of herbicides in Finnish forestry has decreased drastically since the 1970s and 1980s (Figure 3.1, Table 3.2). In 1977 over 160 tonnes (t) of active ingredients were used compared to 0.2 t in 2005.

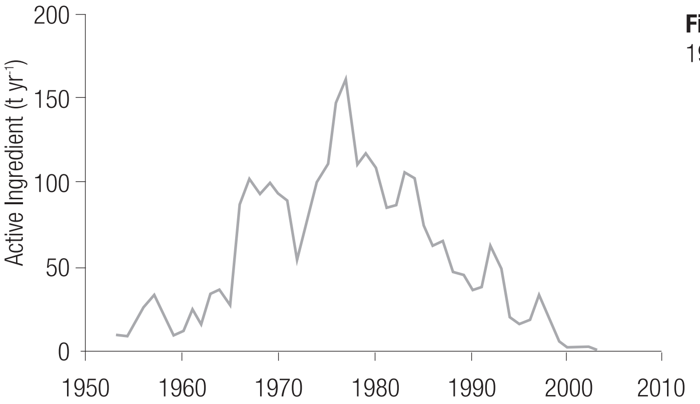

Figure 3.1 I Sales of forest herbicides in Finland 1953–2006.

Crop	Tonnes active ingredient used
Forestry herbicides	0.2
Forestry repellents	0.1
Forestry urea (fungicide)	428.3
Total forestry pesticides	**428.5**
Agricultural herbicides [a]	1077.2
Growth regulators	51.9
Fungicides[a]	255.4
Insecticides[b]	46.5
Total agricultural pesticides	**1431.0**

[a] Forest nurseries included in agricultural products.
[b] Products used to treat seedlings against *Hylobius* (pine weevils) in forest nurseries are included.

Table 3.2 I Pesticide usage on different crops in Finland in 2005. Source: Statistics from Finnish Food Safety Authority at http://www.evira.fi/portal/en/plant_production_and_feeds/pesticides/statistics/

For areas of forest land and agricultural land see Table 3.1.

Policy drivers and pesticide regulation

Finland's national pesticide legislation and regulations have been harmonized according to European Union policy (e.g. Directive 91/414/EEC) and a new law on plant protection was implemented in 2007. In general the goal in plant protection practice is to minimize the use of chemical products and to improve and encourage Integrated Pest Management (IPM) among users. Practical guidance is being further developed and regulated while simultaneously adopting the ongoing European Community action on the sustainable use of pesticides.

The use of pesticides is also affected by legislation in other national policy areas. In forestry, water policy plays an important role and operator protection has become increasingly important. Restrictions on the use of chemical herbicides and pesticides are also published in the voluntary Finnish Forest Certification System (FFCS). A total of 95 % of commercial forests are certified by the FFCS, endorsed by the Programme for the Endorsement of Forest Certificate schemes (PEFC). According to criterion 20 the use of chemical herbicides and pesticides is to be avoided in forest management. This criterion recommends that broadleaf brush is not treated with chemical foliage sprays in forest regeneration areas or in young stands, unless necessary to prevent the spread of fungal diseases through aspen brush in young Scots pine stands. Chemical pesticides and herbicides are used only when unavoidable, for instance in the control of ground vegetation on forest regeneration areas, stump treatment of broadleaved trees and for the control of the large pine weevil (*Hylobius abietis* L.) and treatment of coniferous timber stores in the vicinity of forests to prevent the spread of insect damage (FFCS, 2003).

The northern location of Finland raises environmental risks which can restrict the number of available pesticide products. Forestry use may also need additional inspection of products that are routinely used in agriculture, and this costly work also reduces the interest of manufacturers in developing new pesticides for forestry.

Weed problems

Weed problems still exist in forest nurseries although the production of bare-rooted seedlings has been replaced by container seedlings which are grown partially in plastic houses and have pure peat as a growth medium. In Finland the forest seedling production in 2007 was 164.4 million container seedlings and 1.3 million bare-rooted seedlings (statistics from Finnish Food Safety Authority). Containers are mainly weeded manually as there are limited possibilities for chemical weed control and many previously used herbicides are no longer permitted in nurseries.

In forest regeneration, after clearfelling, soil preparation is carried out to increase seedling growth and decrease the need for vegetation management. However, on better forest site types vegetation management is needed in order to raise the crop successfully. Mechanical weed control, mainly trampling, is used to prevent tall vegetation bending over the seedlings and to prevent snow and ice packing. Major weed species in the establishment phase in regeneration areas on rich forest site types commonly include raspberry (*Rubus idaeus*), grasses (especially *Calamagrostis* spp.) and fireweed (*Epilobium angustifolium*).

Competition with vegetation is much more vigorous on former agricultural fields than on forest land (Photo 3.2, page 62). Agricultural fields have a huge seed bank, e.g. in an abandoned field the average number of viable seeds can be 50 000 m^{-2}. Controlling ground vegetation on long-discarded fields is more difficult than on recently abandoned fields. The same applies to fields cultivated for hay crops compared to fields that have carried cereal crops. Preventative control certainly changes the species composition of weeds from perennials to annuals, but this change is short lived and does not necessarily alleviate the competition situation for tree seedlings. Grasses, e.g. *Deschampsia cespitosa* (tufted hair-grass), *Elymus repens* (common couch grass), *Agrostis* sp., *Alopecurus* sp. (foxtail), *Poa* sp. (meadow grass), can form dominating vegetation for a long time after afforestation.

On forest land, competition with deciduous woody vegetation is typically more severe than with herbaceous species. Two birch species (*Betula pendula, B. pubescens*), aspen (*Populus tremula*) and grey alder (*Alnus incana*) compete with production trees and cause yield losses and damage to the main stems. On fertile sites, competing broadleaves begin to seriously affect the development of production trees some years after stand establishment. Two brushcutting operations are needed before the first commercial thinning. The poorest sites can be grown to the first commercial thinning with only one tending operation. In the northern parts of Finland repeated brushcutting on the same stand is rarely needed even on the most fertile sites.

Harvesting of stumps for bioenergy after final cutting has become a common operation in forests within 100 km of power stations that are utilizing biofuels. Stump harvesting disturbs the forest floor and reveals mineral soil more extensively than conventional soil treatment for forest regeneration. In some studies, stump harvesting has increased the number of deciduous trees (Kardell, 1992). On average, the number of broadleaved stems has been estimated to increase by 50 % on sites where stumps were harvested compared to conventional regeneration areas.

Treatments and alternatives

Current knowledge

Methods and strategies adopted for managing weeds in Finland

Silvicultural systems

Norway spruce is normally regenerated by planting but in some cases the nurse crop method and shelterwood cutting are alternatives. In the nurse crop method small sized deciduous trees are left in the regeneration area to protect planted spruce seedlings from early summer frosts until they have reached 1–2 m in height. The nurse crop also prevents the development of ground vegetation. Since Norway spruce tolerates shade and regenerates easily under other trees, regeneration cutting can be done using the shelterwood method where stem number is first decreased to 300–500 stems ha^{-1}. When regeneration under the stand is abundant stem number is further decreased to 100–300 stems ha^{-1} and then cut later.

Soil preparation

After clearcutting soil is normally prepared to ensure the success of forest regeneration. Soil preparation influences the site's water status, temperature and nutrient conditions, and the competition coming from the ground vegetation. When choosing the site preparation method it is important to know the soil properties of the site. In 2006 a total of 115 410 ha of forest regeneration areas were prepared at a cost of €26.3 million (Peltola, 2007). Soil preparation was by scarification (24 700 ha), harrowing (43 358 ha) and mounding (47 355 ha). Seedlings planted in mounds above the average ground level have less competition from ground vegetation compared with seedlings planted at ground level.

Seedling type

Seedling production in forest tree nurseries has changed radically during the past few decades. In Finland, bare-rooted seedlings have been almost completely replaced by containerized stock which is usually smaller and younger. For example, in 1980 66 % of all Scots pine seedlings produced were bare-rooted compared with only 0.1 % in 2006. The use of small seedlings emphasizes the importance of weed control (Hytönen and Jylhä, 2008).

Mechanical methods

Mechanical weed control is mainly done by trampling the weeds around the seedlings. This has to be repeated several times during the growing season and during several consecutive years. The effect of trampling on competition for water and nutrients is probably minor. The main advantage is that when done late in the season it prevents tall dying vegetation from falling on the seedlings. Falling vegetation and snow and ice pressing seedlings to the ground can cause significant mortality.

Control of woody weeds

Control of woody weeds (140 000 ha in 2006) is typically carried out by brushcutting saw (Photo 3.3, page 63). Some machines have been introduced during recent decades but their cost-efficiency in operations has been poor compared to forest workers with brush-cutting saws. Herbicides against woody weeds are now used in very small amounts. Finnish Forest Certification System (member of PEFC) guidelines limit the use of herbicides on broadleaves to cases when it is necessary to remove aspen from Scots pine stands because of infection by *Melampsora pinitorqua*.

Mulches

Inorganic paper-based mulches have been used on a very small scale in Finland. They can be effective if large enough, if they suppress weeds for at least two or three growing seasons and if they stay in place after fixing. However, more research on the effect of mulching and types of mulches needs to be carried out. Since mulches are rather expensive compared with the price of seedlings there are doubts about their cost-effectiveness.

Biological weed control

Animal grazing as a weed control method is not used in Finland.

Herbicides

In the 1970s and 1980s herbicides were the commonly used method of vegetation management. Present-day use of herbicides is very limited (Figure 3.1); those now in the Finnish market for use in woodlands and nurseries are given in Table 3.3.

Table 3.3 | Herbicides permitted for use in forests and forest nurseries in Finland. Note that because of the ultimately small usage no statistics or estimates are available on actual usage.

Herbicide	Target use
Glyphosate	Conifer regeneration sites before planting or during the dormancy of planted conifer seedlings (otherwise seedlings have to be protected).
Aclonifen	Regeneration sites before planting. In nurseries for treatment of conifer seedling beds during seedling dormancy.
Dichlobenil	Birch planting sites.
Clethodim	Planting sites, effective only on grasses. In nurseries to control *Poa annua* and other grasses on both bare-rooted and container seedlings.
Propaquizafop	Birch planting sites, effective only on grasses.
Isoxaben	In nurseries for treatment of conifer seedling beds.
Diquat	In nurseries on open field bare-rooted seedling beds before sowing.
Quinoclamine	In nurseries for control of liverworts.
Cycloxydim	Planting sites, effective only on grasses. In nurseries to control grasses on both bare-rooted and container seedlings.

Barriers to adopting alternative methods

Environmental pressures have probably had the greatest effect on reducing the amount of pesticide use in Finnish woodlands. The use of chemical herbicides in forestry has been almost totally discontinued. Even though forest certification criteria do not ban their use, certification has decreased interest in the use of herbicides. According to FFSC, herbicides may be used only when unavoidable, for instance for the control of ground vegetation in forest regeneration areas.

Even though use of herbicides has almost completely stopped, alternative measures have not been adopted. There may be several reasons for this. Alternative methods are known to be much more expensive. One major obstacle is that there is insufficient scientific research information available on the effects of various alternatives. For forest owners, using methods that have been inadequately tested is a risk. Also, development of alternative methods has been limited.

Ongoing research

In Finland the most serious problematic sites regarding competition from vegetation are afforested agricultural sites. Studies on afforestation methods have also included vegetation control experiments. Most of the reported studies describe only short-term effects of vegetation competition during the first 2–3 post-planting years. Recently, however, results showing longer-term effects (9–15 years), giving information on the volume growth of trees, are being reported (Hytönen and Jylhä, 2005, 2008; Jylhä and Hytönen, 2006). Alternative vegetation control methods have been little tested (e.g. Siipilehto and Lyly, 1995). In normal regeneration areas studies on the effects of weed control are scarce.

Currently, timing of cleaning and tending of young stands have been studied for better cost-efficiency of operations. In a recent study it was found that timing, i.e. the age of the stand, has a marked effect on the productivity of operations, even if the span between alternative time points is as small as 2 years. A quality assurance system for tending operations has been developed to improve the quality of operations carried out in practice. Although we have gained knowledge on how to treat recently established stands, it is a great challenge to put those operations into practice without proper marketing and data management practices and tools.

Mechanized tending has been tried in the Nordic countries for some decades, mostly in Sweden. Today in Finland there are some machines in commercial operation and new prototypes are being developed. Prospective lack of labour for manual forestry operations is one of the driving forces for developing mechanized silvicultural methods.

Utilizing small-diameter trees for bioenergy may influence the guidelines for management of young stands in the future. New management regimes have been studied using forest stand simulators. At the current wood price levels with governmental subsidies for silvicultural operations, growing small trees for energy may be a profitable alternative in some cases if they are harvested in the first commercial thinning.

In addition to ongoing research, inspection and testing of new herbicides is under way in the forest and in forest nurseries. In the forest the main focus is on prevention of weed germination on fresh planting mounds either before or after planting container seedlings. In nurseries there is an urgent need to reduce the weeding costs of container seedlings; in particular, to address new weed problems that have arisen in the use of transplanted container seedlings. There is, however, very limited interest among pesticide manufacturers to produce new herbicides for forestry.

Studies have recently started in Finland with a hardwood rotting fungus *Chondrostereum purpureum* (Vartiamäki *et al.*, 2008a). The aim is to test the possibilities of using the fungus as a mycoherbicide in controlling sprouting of hardwood stumps in young conifer stands, under power transmission lines and at roadsides. The fungus has previously been studied in The Netherlands and Canada (Scheepens and Hoogerbrugge, 1989; Dumas *et al.*, 1997; Harper *et al.*, 1999; Pitt *et al.*, 1999; De Jong, 2000). In Finland C. *purpureum* has been tested on birch (*Betula pendula, B. pubescens*), aspen (*Populus tremula*), grey alder (*Alnus incana*) and willows (*Salix* spp.). First results have been promising and these studies are continuing (Vartiamäki *et al.*, 2008b).

Future research needs/potential for European collaboration

There are major knowledge gaps in forest vegetation management in Finland. The efficacy of both conventional and alternative methods and their ecological impacts and costs need to be studied in more detail. For example, in addition to the short-term effects of weed control and young stand management, the long-term effects on stand volume growth and across the timescale of the whole rotation should be investigated. Innovative alternative methods should be studied as well as mulches and cover crops, and new herbicides.

The increase in energy wood utilization from clearcutting areas, and especially the harvesting of stumps, is creating new unstudied situations for weed control and young stand management. Existing knowledge on forest vegetation management needs to be reviewed in detail. At the same time, existing unanalysed datasets need to be reviewed to discover which ones may be of scientific interest.

The high labour costs of manual weeding in forest nurseries and the limited possibilities (mainly because of various regulations) for the use of herbicides in forest regeneration sites demand more research and development work. Unlike the situation in agriculture, integrated pest management (IPM) practices have not been fully studied and developed as a tool in forestry. In the context of the European Commission act 'A Thematic Strategy on the Sustainable Use of Pesticides' there could be potential to work more intensively on alternatives to pesticides.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Ecosystem responses

Current knowledge

Effects of weeds on trees

In Finland competition is seen as decreased growth and, in addition, when vegetation cover is high, as increased mortality. Competition mechanisms have not been intensively studied. However, competition for water and nutrients is thought to be more intense than competition for light. Silvicultural studies have recently focused on the impact of ground vegetation on nutrient dynamics and leaching after clearcutting (Palviainen, 2005).

Weeds are also known to affect some pests and diseases; for example voles (*Microtus agrestis*) are known to eat birch and pine bark especially when favoured weed species are in the vicinity of tree seedlings. Vole damage can increase the risk of fungal infections; and on birch planting sites with rich vegetation the oviposition holes of leaf hoppers (*Cicadella viridis*) in the birch bark serve as pathways to fungal infections (Juutinen *et al.*, 1976).

Nature and magnitude of effects

Effects vary, depending especially on tree species and site characteristics. However, research on ecosystem responses has been quite limited.

Impact of control methods

In some cases control of vegetation with inorganic paper-based mulches has increased vole and pine weevil damage in protected seedlings because these pests can more easily find shelter under the mulch. There is no current information on ecological effects of chemical control methods because of their minimal use in forestry.

Ongoing research

At present there are no ongoing research programmes focusing on the ecosystem responses or direct effects of vegetation control on trees but follow-up of some older experiments continues. Research dealing with the role of forest vegetation in the control of nutrient leaching after clearcutting is ongoing.

Future research needs/potential for European collaboration

Much research is still needed to understand the ecophysiological relations of flora and tree seedlings, and how control methods should be linked to these processes. The role of the competition for water and nutrients deserves particular attention.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge

Discussion within the social dimensions of vegetation management has been mostly related to availability of labour for young stand management. Studies on people's perceptions of the landscape effects of tending young stands are mostly positive.

Ongoing / future research

There has been little formal research specifically into the social dimensions of vegetation management within woodlands in Finland. As mentioned earlier, one of the reasons for research into mechanization of vegetation management has been the prospective lack of forestry labour. Availability of forestry labour has been intensively discussed in some reports on the future of the forest sector of Finland.

Future research needs / potential for European collaboration

There is no information available on future research needs at present.

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4 France

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Country background

Forest history

During the Gallo-Roman period (1st–4th century AD), forests covered two-thirds of the metropolitan French territory (Huffel, 1926). During the Middle Ages this proportion decreased dramatically to only 15–17 % of the land area. This residual forest was then severely damaged during the Renaissance period (15th–17th century) by over-harvesting and anarchic management. When Colbert's Forest Ordinance was instituted in 1669 a gradual restoration took place. High forests produced mainly timber wood, especially for the navy and cask production, and coppices were used for firewood. This ordinance also marked the beginning of a true forest science, an approach which gained worldwide recognition.

Since the 19th century the land area of forests has increased owing to the impacts of various wars and a rural exodus which left considerable amounts of vacant agricultural land available for natural tree colonization. In addition, voluntary tree planting has occurred, often approved by governments for different objectives such as erosion control and increased timber production. In two centuries the forest area has increased by 67 % (Cinotti, 1996) and this trend is still important in transforming the landscape. Woodland area increases each year by an average of 68 000 ha (IFN, 2006), with additional areas being spontaneously colonized by woody species. From a management point of view, the decrease in the demand for firewood has led to the transformation of many coppices into coppices with standards, or to high forests, but this trend may be reversed in the coming years with the decreased use of fossil fuels for energy.

Topography and climate

France consists mainly of plains and hills, with two high mountain regions, the Alps in the east to southeast (with Mont-Blanc culminating at 4810 m) and the Pyrenees in the south (culminating at 3404 m), and four older smaller mountains, the Jura, the Vosges and the Ardennes in the east to northeast, and the Massif Central in the centre. The climate of France can be roughly divided in four main zones: Mediterranean, Atlantic, Continental and Mountainous; their climatic features are presented in Table 4.1. Mediterranean climate is characterized by very heavy rainfall in spring and autumn, and a long, warm, dry summer season prone to forest fires. Atlantic climate is wet with temperatures moderated by the ocean. Continental climate is characterized by marked extreme temperatures. In mountainous areas, where forests are present, the climate is cold and wet.

Forest and woodland area today

Woodlands now occupy 15.5 million ha in metropolitan France (IFN, 2006), i.e. 28.2 % of the total land area (Table 4.2). About 60 % of forests are probably native but, as described earlier, they have been greatly reshaped by human activities for one to two millenniums (Huffel, 1926). The remaining 40 % have been progressively planted since the beginning of the 19th century from abandoned agricultural lands (Cinotti, 1996).

Table 4.1 | Climatic features of France.

Climate zone	Temperature (°C)				Annual rainfall (mm)
	Coldest month	Mean annual	Warmest month	Absolute minimum	
Mediterranean	6 to 8	14 to 15	23 to 24	-5 to -10	400–600
Atlantic	2 to 4	11 to 12	17 to 19	-10 to -15	600–1200
Continental	1 to 3	10 to 11	18 to 19	-15 to -25	500–800
Mountainous [a]	-2 to -4	6 to 8	13 to 17	-25 to -30	1000–2000

[a] At the altitudes of forest.

Land use	Area (million ha)	Percentage (%)
Woodlands and forest	15.5	28.2
Agriculture	30.6	55.8
Urban	3.9	7.0
Other	4.9	9.0
Total	**54.9**	**100.0**

Table 4.2 I Land use in France (Agreste, 2006).

The metropolitan French forest is distributed over a large range of biogeographic zones. Most is temperate, with broadleaves dominating in the oceanic and continental plains and conifers in mountains. The Mediterranean area is mainly composed of evergreen species, often very sensitive to fire, so that forest vegetation management (FVM) in that area is almost entirely devoted to fire prevention. The average productivity of the French forest is estimated to be 6 – 6.5 m^3 ha^{-1} $year^{-1}$ (IFN, 2006). High forests (30 %) and mixed forest and coppice with standards (59 %) dominate French forests. The coppice alone is used for firewood and occupies 11 % of the land area (Table 4.3).

Table 4.3 I Surface area (1000 ha) of production forests (IFN, 2006).

Climate zone	Broadleaves	Conifers	Mixed	Total
High forest	2686	1227	488	4401 (30%)
Mixed forest and coppice with standards	5400	2224	1066	8690 (59%)
Coppice	1546			1546 (11%)
Felled, awaiting reforestation				166 (1.1%)

The area regenerated each year is estimated to be 150 000 ha, including forests where different stages (from young to mature) coexist at the same place and time (for example some parts of the Mediterranean, Alpine and Pyrenean forests). The cost per hectare to ensure tree establishment (to a height of 3 m) varies from €1500 to €2500 to more than €6000 according to forest species (for example Douglas-fir versus oak), site (acid versus rich soil) and requirements for fencing, depending on populations of browsing mammals present. The average can be estimated at €3500–€4000 ha^{-1}.

Species composition

At the country scale, broadleaves and conifers represent 71 % and 29 % of the land area, respectively. The main broadleaved species are the oaks (penduncculate oak: *Quercus robur*, sessile oak: *Q. petraea*, downy oak: *Q. pubescens*) which represent 23.7 %, European beech (*Fagus sylvatica*, 9.2 %), sweet chestnut (*Castanea sativa*, 5.3 %), and other broadleaves like *Acer, Fraxinus* or *Prunus* genera (32.1 %). Conifers are dominated by pines, with maritime pine (*Pinus pinaster*) covering 1 million ha concentrated in the Landes in southwest France (7.3 %). Other pines represent 10.3 %, Norway spruce (*Picea abies*) and white fir (*Abies alba*) 8.3 %, Douglas-fir (*Pseudostuga menziesii*) 2.9 %, and other conifers 1.0 % (National Forest Inventory: IFN, 2006).

Ownership

Seventy per cent of metropolitan French forests are privately owned, each having generally only a small area: 1.1 million owners share 10 million ha, with a mean of 3.1 ha (IFN, 2006). Twenty-nine per cent of owners have different occupations, 25 % are farmers and 21 % retired. The remaining forests are public lands, owned by the government (12 %) or local communities (18 %). Government forests are generally very large, with 1.8 million ha divided among 1714 forests.

Forest establishment or perpetuation

High forest is renewed or perpetuated by planting seedlings or natural regeneration. Both systems have been used for a long time but today natural regeneration and species diversity are favoured as much as possible. The windstorm of December 1999 that damaged more than 800 000 ha, including the complete destruction of 450 000 ha (Wencélius, 2002), has particularly contributed to this trend. The coppice is renewed by cutting. Afforestation on former agricultural land is mainly by planting and sometimes by direct seeding.

Statistical data about forest areas, planted or naturally regenerated, are not available. An estimation based on a renewal rate of 1 % gives a figure of 150 000 ha every year for existing forests, along with an estimated 166 000 ha temporarily unforested area every year (IFN, 2006). Added to this is the afforestation of former agricultural lands, probably representing several thousand ha each year, although this is now becoming less important.

Policy drivers – certification

Each year sees an increase in certificated forest area in France. The PEFC (Pan-European Forest Certification) is the most frequently used certification system. Almost all public forests are certified (1.6 million ha for government forests and 1.2 million ha for communal forests), and the area for private properties is increasing (1.5 million ha; PEFC-France, 2006). Therefore, at present, nearly a third of the forest area is certified. More than 1000 French companies linked to the wood sector have also chosen a PEFC control. The PEFC does not forbid herbicides or pesticides but limits their use, particularly in sensitive areas like river banks and water catchments. Some owners also adhere to different charters like Natura 2000, and many local community organizations establish territorial charters for their wooded areas.

Herbicide use

As mentioned earlier, herbicides are not forbidden in French forests, even when they are certified, but their use is strictly controlled and very limited in comparison with agriculture (Table 4.4): about 50 000 ha of forest stands are treated each year out of a total of 15.5 million ha (Gama *et al.*, 2006). Herbicides are generally used from 0 to a maximum of 3 times during the life-cycle of a forest stand (generally more than 80 years), to ensure tree establishment in natural regeneration or tree plantation. To be used in France, a herbicide must have an authorization from the French government; this is granted for a given culture and for a precise use. There are three main categories of herbicide use: brushwood clearing before crop tree set up, clearing of vegetation around established young trees, and suppression of stumps or sprouting of standing trees. The number of commercial compounds authorized for use in the forest is continuously decreasing, about 38 today, and only 23 are commonly marketed (Gama *et al.*, 2006). The use of specific herbicide application is also regulated, for example recommendations are made for the minimum no-spray buffer zones from rivers and drains, for disposal of herbicide packaging, and the health and safety of operators.

Table 4.4 I Estimation of herbicide and pesticide application number per year and area treated for different crops in France (Rabaud and Cesses, 2004 and www.quid.fr/2007/agriculture).

Crop	Total crop area (‘000 ha)	Mean herbicide application number (per year)	Area treated by herbicide (%)	Area treated by herbicide (‘000 ha)	Pesticide application number (per year)	Area treated by pesticide (%)	Area treated by pesticide (‘000 ha)
Wheat	5288	2.3	98	5182	3.7	96	5076
Barley	1610	1.9	97	1562	2.9	93	1497
Maize	1633	2.4	98	1600	1.3	38	620
Sugar beat	396	9.7	100	396	2.8	96	380
Potatoes	147	2.1	98	144	14.1	100	147
Forest	15500	0.02 [a]	0.3	50	?	?	?

[a] One application every 50 years.

Target species

Weeds in French forests develop to varying degrees mainly according to light and fertility, and are often highly diversified. In some circumstances, forest plots can be entirely colonized by certain social species that rapidly occupy the whole available space (Table 4.5). These species can be problematic because they can jeopardize tree regeneration and seedling growth through competition for resources (water, nutrients, light) and therefore FVM is often designed to control their development. Conversely, they can favour tree establishment through direct facilitation of nutrients (e.g. by supplying nitrogen), or indirectly, such as a bramble bush suppressing a light-demanding competitor (Frochot *et al.*, 2002). In Table 4.5 species considered as competitors are annotated with C, and those as facilitators with F. Their importance in the understorey of established forests has been assessed by the French National Inventory (IFN in Gama *et al.*, 2006) but the abundance of some light-demanding species found in open-field plantations could be underestimated.

Table 4.5 | Abundance of some social plant species found in French forests and their effect on crop tree seedlings.

Species	Frequency (%) in the forest understorey [a]	Interaction type when abundant: C = competition, F = facilitation		
		Infertile acidic soil	Acidic to neutral soil	Calcareous dry soils
Rubus fruticosus Bramble	63.5	F	C	F
Pteridium aquilinum Bracken	29.1	C	–	–
Carpinus betulus Hornbeam	29.0	–	C or F [b]	F
Castanea sativa Sweet chestnut	21.0	C	–	–
Cytisus scoparius Broom	13.6	F	C	–
Brachypodium pinnatum False brome	12.9	–	–	C
Calluna vulgaris Heather	12.5	C or F [c]	–	–
Molinia caerulea Purple moor-grass	11.5	C	–	–
Ulex europaeus Gorse	7.6	C	–	–
Juncus spp. Rushes	7.0	C	C	–
Deschampsia cespitosa Tufted hair-grass	6.8	–	C	–
Clematis vitalba Traveller's-joy	6.6	–	–	C
Agrostis spp. Bents	5.3	C	C	C
Robinia pseudoacacia False acacia	5.0	C or F	C	C
Epilobium angustifolium Rosebay willowherb	2.0	C	C	–
Carex brizoïdes Sedge	0.6	C	–	–
Phytolacca americana American pokeweed	0.5	C	–	–
Calamagrostis epigeios Wood small-reed	0.4	C	C	–

[a] Source: IFN in Gama *et al.* (2006).
[b] Can be used as facilitator if controlled.
[c] Competitor or facilitator depending on the tree species considered, e.g. oak and spruce or pine, respectively.

The list of species shown in Table 4.5 is not exhaustive: species such as *Salix caprea* (goat willow), *Betula pendula* (silver birch), *Cirsium* sp. (thistles), and other grasses, e.g. *Holcus* sp. (soft-grasses), *Brachypodium sylvaticum* (false brome) can be added. In addition there are species of open areas, usually in the case of afforestation of former agricultural lands, mainly opportunistic grasses such as *Agropyron repens* (common couch) and *Agrostis* sp. (bents). Bramble is by far the most frequent species in French forests (63.5 % of the surveys) and is able to colonize most sites. Bracken is also well represented but only in acidic soils (29.1 %). Other ferns are also very abundant together with tall forbs, e.g. *Cicerbita* sp. (blue sow-thistle), *Adenostyles alliariae* (hedge garlic), in wet mountainous forests. Around 10 species are important with frequency rates ranging from 5 to 14 %. The effect of some species, competition or facilitation, depends on the fertility of the soil. For example the high and dense cover of bramble in fertile and well-watered soil can inhibit crop tree growth, whereas a low cover of bramble in infertile or dry soil may conversely indirectly facilitate crop tree survival.

In addition to the main problematic species shown in Table 4.5, other less represented species can also be competitive when combined, which emphasizes the interest of functional classifications based on species traits and effects on crop species (Table 4.6). It does not mean that each species belonging to a group is always a competitor but it could be in some circumstances and must be considered with care.

Table 4.6 | Forest vegetation classification according to life forms, functional traits and main effects on crop tree species (Frochot *et al.*, 2002; Balandier *et al.*, 2006); bold = most common effect.

Growth form	Potential inhibitor effect	Potential facilitator effect	Example of species or genera
Graminoids	**Water** Nutrient		Perennial grasses, *Carex, Juncus, Luzula*
Forbs and legumes with a dense cover	**Light** Water Nutrient	Inhibition of graminoid growth Nitrogen supplying (legume species)	*Epilobium* *Trifolium* *Rumex*
Dwarf shrubs, climbers and ferns	**Light** Water + allelopathy *(Calluna)* + crushing *(Clematis, Pteridium)*	Inhibition of graminoid growth Climatic protection Protection against predators	*Rubus fruticosus* *Rubus idaeus* *Calluna vulgaris* *Cirsium arvense* *Pteridium aquilinum* *Ulex europaeus* *Cytisus scoparius*
Mid-storey shrubs	**Light** Water	Inhibition of graminoid and small shrub growth	Social woody perennials *Salix* sp. *Corylus avellana* *Cornus mas*

The graminoid type includes grasses, rush and carex, which are highly capable of taking up water and nutrients to the detriment of crop trees. Vegetation surveys made after the storms and subsequent windthrow of December 1999 showed that the frequency of graminoids was 28 % for a total of 23 species, whereas each of them taken alone was not very abundant (Mangin and Lacombe, 2006).

Sorting vegetation by functional types (Frochot *et al.*, 2002; Balandier *et al.*, 2006) widens the notion of competitive species and allows better identification of potential interactions with crop tree seedlings. The competing vegetation can have some inhibitory effects, reducing tree seedling growth but also in some cases leading to seedling death and so preventing tree regeneration. Conversely, it can help seedling establishment in some circumstances and especially favour the future stand quality. Therefore characterizing both the competitive and the facilitating effects of different vegetation types helps to design better FVM strategies.

Treatments and alternatives

Background and current knowledge

Most of the French forest area is extensively managed, and often with multipurpose objectives such as quality wood production, recreation, landscape or environmental conservation. In that context, the main goal of FVM is to favour tree stand establishment rather than improving tree growth rate. A stand is considered established when trees are sufficiently high to dominate the vegetation and tolerate large herbivore damage (i.e. 2 to 3 m tall). The objective is to control weeds impeding tree establishment, without eradicating them, and with a minimization of costs and number of technical operations (Frochot *et al.*, 2002; Frochot, 2006).

When the forest is intensively managed (e.g. *Pinus pinaster* in the Landes, *Pseudotsuga menziesii* in central France), tree growth rate improvement is added to the necessity of warranting stand establishment by FVM. Finally in the Mediterranean forest, the main goal of FVM is to prevent fires starting or spreading.

Methods and strategies adpoted for managing weeds in French woodlands

Chemical control

Herbicides are generally used when forest weeds are likely to jeopardize tree seedling survival and growth (Gama *et al.*, 2006). When forest sites are invaded by potential competitive social perennial species such as *Pteridium aquilinum*, *Rubus fruticosus* and *graminoids*, one foliar application of a herbicide is usually made before tree regeneration; it is generally effective for between 2 and 4 years (e.g. asulam on bracken, Table 4.7). After tree planting, treatments are only used when essential, with selective herbicides applied along tree seedling rows. However, in intensive plantations non-specific herbicides (e.g. glyphosate) are applied locally around tree seedlings, often over a period of several years.

When correctly managed, herbicides control weeds efficiently, durably and selectively directly around tree seedlings. They can also drive the vegetation dynamic towards a species composition more favourable to tree seedling establishment and growth. However, the impact of synthetic pesticides on the environment is often questioned by forest managers, and more generally by society, whereas herbicides are economically defended in some silvicultural systems (for example *Pinus pinaster* in the Landes region). Some studies have shown that the composition of flora is relatively unaffected by herbicide treatment (Dreyfus, 1984; Gama and Dumas, 1999). One point in favour of herbicides is that fewer interventions are needed compared with mechanical treatments, and thus overall disturbance is generally lower.

Table 4.7 | Some examples of herbicides used in France. The area treated annually is estimated to be 50 000 ha (Gama *et al.*, 2006).

Active chemical compound	Utilization rate	Purpose
Asulam Hexazinone (*until 2007*) N-phosphonométyl glycine (glyphosate, sulphosate)	High	*Pteridium aquilinum* control Pine and other conifers: weeding Control of *Rubus fruticosus*, *Clematis vitalba* and other plants
2,4-D (alone or associated) Dichlorprop (associated with 2,4-D) Fluazifop-p-butyl Propyzamide Quizalofop-ethyl Triclopyr (alone or associated to 2,4-D)	Medium	Woody species devitalization Woody species devitalization Grass control Grass control Grass control Small shrub control
Clopyralid Oxyfluorfene (associated with propyzamide)	Low	*Cirsium* sp. control Broadleaves and some conifers: weeding
Dichlobenil	Very low	

The shelter technique

The shelter technique aims to preserve part of the stand cover during harvesting so that light in the understorey is sufficiently low to prevent or slow down the development of light-demanding weeds but above the threshold that allows tree seedling growth (Pagès *et al.*, 2003; Pagès and Michalet, 2003). In the past the technique was particularly applied to shade-tolerant species such as *Fagus sylvatica* (beech); today it is especially used in individual or group selection silviculture. However there are problems with the technique. First, it is mostly based on empirical knowledge and requires future research in order to become widely used, as, for example, the proportion of adult tree cover or the light requirement of different tree species. Second, it is difficult to harvest crop trees without damaging tree seedlings.

Nurse species

The nurse species technique aims at sheathing crop trees with other tree species or tall shrubs. The objective of the nurse vegetation is to improve tree growth, to improve tree bole form quality and to protect trees against large herbivores. It also helps to decrease crop tree density. The technique is often used in oak (*Q. petraea, Q. robur*) plantations in forest stands with good water availability (Démolis and Jamey, 1988; Collet *et al.*, 1998). Natural woody species, e.g. *Betula* sp. (birch) and *Carpinus betulus* (hornbeam), are used as nurses and prevent site colonization by perennial grasses. The technique is also used in afforestation of former agricultural lands, mostly with valuable species, e.g. *Juglans* sp. (walnut) and *Prunus avium* (wild cherry) (Van Lerberghe and Balleux, 2001). In this situation, the nurse trees are planted, and the cost linked to that operation limits maximum tree density to a level needing a control of additional vegetation (by herbicide, mulch) during the first few years.

Cultivation

The cultivation technique is widely used, with traditional tools (plough, disc) attached to a tractor. The goal is to decompact the soil before planting and slow down weed colonization. Cultivation on its own can be sufficient in dry or unfertile soil to assure tree establishment but on fertile sites additional operations are needed as forest weeds may rapidly recolonize the stands afterwards. The technique cannot be used after tree planting because of the risk of damage when applied too close to the crop tree, where weed competition is the most intense. However, a scarifying tool with spaced blades is sometimes successfully used to partially uproot bramble (*Rubus fruticosus*) in natural oak or beech regeneration. Soil cultivation is also often used in intensive silviculture between rows to control weeds in well-developed stands with the aim of improving crop tree growth, e.g. *Pinus pinaster, Populus* sp. (poplars).

Small mechanical tools attached to a mini-tractor (Photo 4.1, page 63) have been successfully used for some years for local soil preparation, rather than the whole surface, before the planting (Wehrlen, 1998, 2006). A mechanical hoe can also be used to suppress weeds directly around the crop tree seedling instead of manual harrowing. These mechanical mini-tools are supple and easy to use. They can penetrate established stands without disturbing the soil structure too much and their relatively high cost is balanced by both the reduction of the cultivated surface and their efficiency.

Mechanical mowing and brushcutting tools

These tools are frequently used to reduce the height of tall weeds shading crop tree seedlings. Manual tools (scythe, lopping knife) are used in plantation and natural regeneration to clear the vegetation around the canopy of small trees, but the operation often has to be repeated several times before crop trees dominate. Tractor-driven tools are sometimes used in natural regeneration but more usually to crush the vegetation between some rows, to allow access and enable checking of the health of the tree seedlings. They are also used in the Mediterranean region to suppress the inflammable vegetation of the understorey, even in rugged topography. However both manual and motorized tools strongly disturb the habitat, especially for animals, and they destroy bird’s nests during the breeding period.

Mulching

Primarily used for plantations on former agricultural lands, mulching consists of laying a material (a mulch) on the ground surrounding the tree seedlings which forms a screen to stop the growth of competitive natural ground vegetation. Mulching limits soil water loss and contributes to soil quality by regulating temperatures, improving structural stability and maintaining the availability of nutrients (Van Lerberghe and Gallois, 1997).

Many types of mulches are available, for example crushed wood (Photo 4.2, page 63). Black polyethylene films are the most commonly used owing to their low cost, high durability and their effectiveness in aiding tree growth (Van Lerberghe and Balleux, 2001; Frochot *et al.*, 1992). Once worn, these plastic materials become wastes and need to be eliminated. Dumping, burning and burying are prohibited: the non-polluting solution is to collect and recycle them but it is expensive as it is entirely the forester’s responsibility (Van Lerberghe and Six, 2004). In the past few years, new biodegradable products made of wood fibres, cork or natural fibres (linen, hemp and coconut) have performed almost as well as those made from plastic materials and as well as chemical weeding (Van Lerberghe, 2004). Their use is increasing and promising (Sourisseau, 2004). Some of these new products are being developed further to increase their resistance to biological and climatic factors responsible for their breakdown. They have already shown durability of between 24 and 36 months and sometimes longer.

Prescribed burning

Prescribed burning is essentially used to prevent fire initiation and spread in the Mediterranean area. The low vegetation is burned with care during periods of low fire frequency (mostly winter). The technique is especially useful in areas that are difficult to access. The technique is cheap but leads to important on-site disturbances.

Biological control

Vegetation control using biological agents (disease, insects) is not used in French forests. Controlled grazing in forests is not very common, except in the Mediterranean and mountain areas or in the case of plantations with wide spacing around valuable tree species. In these situations trees are specifically protected against grazing animals (Balandier *et al.*, 2002) and generally weeded locally around tree trunks during tree establishment to limit competition from grasses for water and nutrients (Balandier *et al.*, 2008).

The technique of cover plants or cover crops is at the experimental stage (Frochot and Balandier, 2005; Ningre and Koerner, 2004; Ningre *et al.*, 2004; Provendier and Balandier, 2004). It consists of controlling the most aggressive plants (i.e. the most competitive) by sowing a mixture of plants or crops that have a low competitiveness for resources (Reinecke, 2000). By colonizing the soil in time and space this mixture is expected to limit the growth of the most competitive plants, at least until tree seedlings have become well established (Photo 4.3, page 63). The sowing of cover plants has been practised for a long time in farming, especially in vineyards, with various aims: protection of soils against erosion and leaching of minerals, control of fruit production. Cereals and especially rye (*Secale cereale* L.) have been used in French woodlands in direct seeding mixtures with oak and pine seeds (Cotta, 1822). The technique is promising but needs to be improved, in particular for the selection of non-competitive cover plants adapted to different soils and climates.

Ongoing and future research

Ongoing research also aims at designing alternatives to herbicides or mechanical tools in FVM. For example, experiments are under way to test the efficiency of methods of ecological engineering like the use of mixtures of cover plants to limit the development of the most competitive natural graminoids. More environmentally friendly techniques like the use of biodegradable mulches or mechanical mini-tools are also being tested with the aim of controlling the main competing weeds. Future research, for example into techniques such as the use of shelterwood, will build on this trend. French teams often collaborate to conduct this research. Good links have been established with researchers in Germany, Sweden, Belgium, Spain, and with Canada, which will be expanded in the future.

Ecosystem responses to FVM

Current knowledge

In French soil and climatic conditions, forest weeds surrounding young trees generally reduce their growth and eventually their survival (Frochot *et al.*, 2002; Balandier *et al.*, 2006). In open fields the inhibitory effect increases with the proximity to the tree seedling; the absence of vegetation on a radius of only 10 cm is sufficient to have a significant effect on tree growth, for example on *Populus* sp. (Frochot, 1984). The inhibitory effect depends also on the vegetation type, perennial grasses being generally more deleterious than forbs or bramble for example. In many cases the competition for water and, to a lesser extent, nutrients is responsible for those inhibitory effects. The order of plant establishment with time, their spatial arrangement, below- or above-ground, the availability and heterogeneity of resources, can greatly modify the relationships between vegetation and tree seedling. Even in closed or semi-closed forest stands the understorey vegetation can seriously deplete the water supply, as is the case of *Molinia caerulea* in *Pinus pinaster* stands (Loustau and Cochard, 1991). However, this relationship is also mediated by light availability. Most competitive species are light-demanding species, with their development increasing with light availability. Consequently, their development and competitive effect for water are highly dependent on the understorey light level. Negative interactions are also reported to come from allelopathic effects, for example with some *Erica* spp. (Gallet and Pellissier, 2002) or grasses such as *Molinia caerulea* (Becker, 1984). However a true allelopathic effect is often very difficult to demonstrate in natural conditions.

Conversely, the vegetation around young trees can have beneficial effects (Frochot *et al.*, 2002; Gama *et al.*, 2006). It may reduce tree seedling water demand by decreasing light, maximum temperature, wind speed and vapour pressure deficit (Michalet, 2007). Spring or autumn frost risks (decrease in night radiation) are also limited, at least for seedlings beneath the vegetation, e.g. *Fagus sylvatica*: Ningre and Colin (2007), *Fagus* sp. and *Abies alba* (silver fir): Michalet *et al.* (2008). Tree seedlings surrounded by vegetation can also have better stem elongation (Collet *et al.*, 1998) and be protected from large herbivores, especially in woody vegetation (Démolis and Jamey, 1988). Indirect facilitation is also encountered; for example adult trees and shrubs can have a beneficial effect on tree seedling growth indirectly through reduced competition from light-requiring forbs and grasses (Pagès *et al.*, 2003; Kunstler *et al.*, 2006); such an effect is also assumed to occur for *Rubus fruticosus* in particular conditions (authors' personal observations).

Ongoing research

Much of the ongoing research is related to the windstorms of December 1999, and particularly to forest reconstitution. In the context of reduced financial support for forests, whatever the considered tool, research focuses on the cheapest and consequently the most natural way to restore forest ecosystems. Research on FVM follows this trend, aiming towards a better understanding of natural vegetation dynamics in different soil and climatic conditions, forest weeds and tree seedling responses to changing light availability, and to limit technical operations only to situations when they are strictly needed, even if tree growth is reduced.

Future needs

A better design of efficient FVM would be based on a better understanding of fundamental knowledge on the competitive abilities of weeds in relation to tree seedling establishment and growth, in different environmental conditions. However a species by species approach is quite impossible and we obviously need to identify the critical traits that characterize weed competitive ability, not in absolute terms, but relative to tree seedling establishment, which could be quite different. This has to be included in a dynamic framework to take into account the effects of different FVM techniques, vegetation growth, and in the context of the current changing climate. We should also address the potential risks of invasion by exotic weeds. Finally we acknowledge that most of our focus has been on plants and we would like to stress the importance of conducting research on the effects of FVM on water quality and other organisms, such as insects, birds, soil fauna and microbes.

Society and vegetation management

No national survey is available on the practice of the different above-described methods of vegetation control. Some assessments suggest that only 25 to 30 % of the forest area that is renewed or created each year is treated by herbicides. Managers' perception of herbicides is very variable. Some, for economic purposes, utilize herbicides when needed as a complement to mechanical operations and in accordance with certification rules. This is particularly the case for intensive management systems and for plantations on former agricultural lands. However most managers are reluctant to apply herbicides, for ideological reasons, or simply due to the lack of knowledge about this tool. This behaviour is common in extensive management systems and public forests. Thus, they use traditional mechanical methods which are often less efficient and more expensive, or they do nothing. Consequently they are often expecting alternative techniques, as shown by their participation in technical demonstration days which show-case new materials such as mini-cultivation (Wehrlen, personal communication).

The place and future of pesticides in forests has been debated among non-governmental organizations, managers and researchers, with the supervision of the French Agricultural Ministry. Recommendations for safe and environmentally friendly use of those products in forests were subsequently issued (Barthod *et al.*, 1994). However there is no real debate at the society level.

Ongoing and future research

To our knowledge, there is no ongoing research in France on the social acceptance of herbicides. For the future, social research is needed not only on FVM but more globally on the human role in forest ecosystems, which is often seen as thriving and producing many services to society with little or no help.

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5 Germany

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Country background

History

From the early 19th century the historical development of forestry resulted in mono-species coniferous forest types, mainly *Picea abies* [L.] Karst. (Norway spruce) and *Pinus sylvestris* L. (Scots pine), being extended far beyond their natural limits. Some forest scientists observed this development with unease (e.g. Cotta, 1828). Despite Cotta's recommendation, at the end of the 19th century forests throughout Germany still consisted mainly of coniferous, mostly mono-species stands. However, in response to huge salvage fellings due to biotic and abiotic damage, and to the very popular idea of continuous cover forestry developed by Möller (1922), broadleaves were established between 1923 and 1942. When the first economic recession after World War II took place (around 1965) the trend towards deciduous, mixed-species forests slowed down (Knoke *et al.*, 2008). The proportion of deciduous trees in stands established at that time was only 30 %.

From 1980 onwards a shift in species composition towards deciduous trees was reached, not only by replacing coniferous trees with broadleaves of one species, but also by planting or direct seeding of broadleaves below the canopies of pure coniferous stands (von Lüpke *et al.*, 2004). The conversion of pure stands into mixed-species stands was justified mainly by expected ecological advantages. In fact, recent economic research shows that from the risk-averse viewpoint, greater value can be expected from a mixed-species forest compared to a monoculture (Knoke *et al.*, 2005, 2008).

In general present-day forestry in Germany, at least in public woodlands, is geared towards so-called 'close-to-nature', 'nature-based' or 'near-natural' concepts. These approaches prefer selective cutting systems in usually mixed-species forests including native tree species, attempting to minimize interventions and often preserving a continuous forest cover, with the aim of balancing timber production and societal demands like recreation, protection and habitat creation. However, on suitable sites productive non-native species such as Douglas-fir (*Pseudotsuga menziesii*) or red oak (*Quercus rubra*) are cultivated as well.

Topography and climate

The topography and the climatic conditions vary considerably throughout the country. The elevation ranges from sea level in the north up to nearly 3000 m in the Alps. Woodlands are mainly concentrated in low mountain ranges or on poorer soils were agriculture was not efficient in the past. The mean precipitation is 798 mm yr^{-1} (average of the 30-year mean 1961 to 1990 of more than 4500 meteorological stations). However, there are stations with 399 mm yr^{-1} (eastern central Germany – Sachsen-Anhalt) and those with 2450 mm yr^{-1} on average (in the Alps, Bavaria; data from Deutscher Wetterdienst: www.dwd.de). The mean annual temperature is 8.4 °C. In January the 30-year mean temperature is -0.5 °C (mean out of 472 meteorological stations). However, there are meteorological stations with a value of -11.2 °C and those with 3.1 °C. The corresponding values in July are 17.1 °C on average with a range of 2.2 to 19.9 °C (depending on the site of the station). Like the other climatic attributes the days with frost vary considerably. In central Germany around 75 frost days per year are common.

Woodland area

Woodlands occupy 11 075 799 hectares or 31.0 % of the total land area of Germany (Table 5.1). There are however distinctive variations in forest cover between the 16 German federal states (Table 5.2). As a consequence of intensive utilization of forests in the past 1000 years, no virgin forests remain but reserves and national parks have been established since 1970. These protected forests comprise 92 366 ha; harvesting or forest interventions are prohibited. The wooded area has increased between 1987 and 2002 at a rate of about 5100 ha per year. (This figure includes only the western federal states, i.e. the states which became part of the Federal Republic after the reunion in 1990 are not considered.) Although large regional differences exist, the forests are highly productive. Between 1987 and 2002, 12.12 m^3 ha^{-1} yr^{-1} had been produced on average (only the western federal states). It is presumed that the present value is lower because the productivity of the sites in the states, which became part of the Federal Republic after the reunion in 1990, is generally lower.

Because of the high percentage of natural regeneration, which, in many cases, grows over decades under the shelter of overstorey mature trees, reliable numbers on annual regeneration area are difficult to obtain. In fact regeneration below the canopy of mature stands was found in the national forest inventory in 2002 on 2 225 320 ha. Assuming 20 years of sheltering by overstorey trees, 111 226 ha are regenerated every year. This value includes approximately 35 000 ha regenerated artificially by planting and direct seeding. The cost for artificial regeneration varies between €4000 and €5000 per ha and depends on tree species (different spacings, plant sizes) and regeneration method. In some cases (mainly private forests) additional costs for fencing against game browsing is necessary.

Land use	Area (ha)	Percentage (%)
Forests	11 075 799	31.0
Agriculture	17 151 600	48.0
Urban / Other	7 474 818	20.9
Total	**35 702 217**	**100.0**

Table 5.1 I Land use in Germany. Source: Forests – Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2005); Agriculture – Statistisches Bundesamt.

State	Woodland area (ha)	Percentage (%)
Baden-Württemberg	1 362 229	38.1
Bayern	2 558 461	36.3
Brandenburg (inluding Berlin)[a]	1 071 733	35.3
Hessen	880 251	41.7
Mecklenburg-Vorpommern	534 962	23.1
Niedersachsen (including Hamburg and Bremen)[a]	1 162 522	23.8
Nordrhein-Westfalen	887 550	26.0
Rheinland-Pfalz	835 558	42.1
Saarland	98 458	38.3
Sachsen	511 578	27.8
Sachsen-Anhalt	492 128	24.1
Schleswig-Holstein	162 466	10.3
Thüringen	517 903	32.0
Total	**11 075 799**	**31.0**

[a] The cities Berlin, Hamburg and Bremen are also federal states but they have only a small wooded area.

Table 5.2 I Woodlands of the German federal states. Source: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2005).

Species composition

Whereas under natural conditions European beech (*Fagus sylvatica* L.) would be the predominant tree species, its current portion is only 14.8 %. In fact conifers at 57.6 % are more frequent than broadleaves (Table 5.3) but with introduced species such as Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in small proportions.

Tree species	Area (ha)	Percentage (%)
Oak *(Quercus* sp.*)*	1 010 555	9.6
Beech *(Fagus sylvatica)*	1 564 806	14.8
Other hardwoods *(e.g. Acer* sp., *Fraxinus excelsior, Ulmus* sp., *Carpinus betulus)*	621 707	5.9
Softwoods (e.g. *Betula* sp., *Populus* sp.*)*	1 039 122	9.8
Norway spruce *(Picea abies)*	2 978 203	28.2
Silver fir *(Abies alba)*	162 016	1.5
Douglas-fir *(Pseudotsuga menziesii)*	179 607	1.7
Scots pine *(Pinus sylvestris)*	2 466 797	23.4
European larch *(Larix decidua)*	297 787	2.8
Presently unstocked	247 058	2.3
Total (only productive wooded area)	**10 567 660**	**100.0**

Table 5.3 I Tree species composition (productive wooded area). Source: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2005).

Ownership and subsidy regime

Roughly speaking half of the forests in Germany are publicly owned (Table 5.4). However, as a consequence of history there are considerable differences between regions and federal states. For example Baden-Württemberg has 39 % corporate forests, 36 % private forests and 25 % state forests (including marginal national forest area), whereas Bavaria is characterized by only 14 % corporate forests, 54 % privately owned forests and 32 % state forests (including marginal national forest area).

The regulations on subsidies vary greatly between the federal states. As a rule the availability of government grants depends on the tree species envisaged for regeneration. In Bavaria, for example, only the regeneration of broadleaves and silver fir is subsidized; and if only these species are used, 100 % of regeneration costs are covered.

Ownership	Area (ha)	Percentage (%)
National forests	409 340	3.7
State forests (federal states)	3 276 661	29.6
Corporate forests	2 160 189	19.5
Private forests	4 823 722	43.6
Account in trust (to be sold)	405 887	3.7
Total	**11 075 799**	**100.0**

Table 5.4 I Land use in Germany. Source: Forests – Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2005); Agriculture – Statistisches Bundesamt.

Silvicultural systems and certifications

In contrast to medieval times when coppice with standards and coppice systems were frequent, at present they cover only 0.7 % of the productive wooded area, and high forests are now dominant. Monocultures can be found on 27 % of the forested area. Single-storeyed stands represent 46 % of the productive wooded area, 45 % are two-storeyed and 9 % are multi-storeyed (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 2005). Harvesting systems depend on tree species. In general clearcutting is avoided (and in some states it is restricted, at least in public forests) and regeneration fellings which span up to 30 years are preferred. A total of 7 193 844 ha are certified by PEFC (as of 31/12/2006) and 554 994 ha (as of 2005) by FSC. Thus 70 % of the total woodland area is certified.

Herbicide use and comparisons

As a result of the recent shift towards ‘close-to-nature’ concepts herbicide use in the public forests of all federal states is restricted to exceptional circumstances. In some state forests the application of herbicides and fungicides is even prohibited. The recommendation is that herbicides should be used only if there is no other option to control competing ground vegetation. As a consequence the public wooded area treated with herbicides is marginal (Table 5.5) and has been continuously decreasing (Table 5.6). No information on annual herbicide use is available for private forests.

Wulf and Wichmann (1989) provided some data on forests of all ownerships for West Germany only. A rough estimation of herbicide use in forests in Germany is given by the data in Table 5.7. The area treated with herbicides was estimated on the basis of a poll; 16 out of 44 crop protection product companies answered the question about active ingredient from their products in kg sold in 2006 for the use in forestry (inclusive of forest nurseries). However, specific data on the amount of pesticide use in forestry in kg of active ingredient is not available.

Table 5.5 | Public forest area treated with crop protection products in Germany.

Species	Area treated with herbicides in 2006 (ha)	Area treated with herbicides in 2006 (% of total state forest area)	Area treated with crop protection products in 1996 (% of total state forest area) [a]	Area treated with crop protection products in 1997 (% of total state forest area) [a]
Baden-Württemberg	19.5[b]	0.002	0.8	0.6
Bayern	0[b]	0.000	0.2	0.2
Berlin	0[b]	0.000	N/A[d]	N/A[d]
Brandenburg	N/R[c]	N/R[c]	8.5	5.4
Bremen	N/R[c]	N/R[c]	N/A[d]	N/A[d]
Hamburg	N/R[c]	N/R[c]	N/A[d]	N/A[d]
Hessen	0[b]	0.000	N/A[d]	N/A[d]
Mecklenburg-Vorpommern	N/R[c]	N/R[c]	2.2	3.1
Niedersachsen	105[b]	0.031	2.1	1.6
Nordrhein-Westfalen	N/R[c]	N/R[c]	0.1	0.1
Rheinland-Pfalz	13[b]	0.006	1.2	0.3
Saarland	0[b]	0.000	0.3	0.3
Sachsen	48.5[b]	0.025	0.9	1.2
Sachsen-Anhalt	N/R[c]	N/R[c]	2.2	1.4
Schleswig-Holstein	N/R[c]	N/R[c]	N/A[d]	N/A[d]
Thüringen	N/R[c]	N/R[c]	2.0	2.3

[a] Data from Berendes and Wulf (2000).
[b] Data from a poll in 2007.
[c] N/R: no reply to the poll.
[d] N/A: data not available.

Table 5.6 | Area of the state forest of Bavaria treated with crop protection products.

Year	Area (ha)
1985[a]	6925
1986[a]	7346
1991[a]	3122
1996[a]	1498
1997[a]	1742
2000	0

[a] Data from Feemers and Blaschke (1999).

Table 5.7 | Estimated forested area treated with crop protection products in Germany.

Pesticide type	Area in 2006[a] (ha) (% of forested area)	Area in 1985[b] (ha) (% of forested area)	Area 1986 (ha) (% of forested area)
Forestry herbicides	8750 (0.08)	10 100 (0.14)	9900 (0.13)
Forestry insecticides / rodenticides	51 000 (0.46)	23 100 (0.31)	23 100 (0.31)
Forestry fungicides	240 (0.00)	1500 (0.02)	2800 (0.04)
Forestry repellents	61 000 (0.55)	46 900 (0.64)	47 900 (0.65)
Total forestry pesticides	120 990 (1.09)	81 600 (1.11)	83 700 (1.14)

[a] Estimation for Germany (wooded area of 11.08 million ha) based on industrial figures given by 16 out of 44 crop protection product companies in 2006.
[b] Estimation for West Germany (wooded area of 7.36 million ha; Wulf and Wichmann, 1989).

Policy drivers and pesticide regulations

Repeated and large-scale herbicide treatments are avoided as 70 % of the wooded area in Germany is certified by PEFC or FSC. Therefore the use of pesticides in public forests is very uncommon, at least restricted, and in some federal states prohibited. Private woodland owners however tend to use herbicides more frequently but only in cases where other options like mechanical control are too laborious or costly. Generally speaking forest woodland owners who run a non-organic agricultural farm seem to use pesticides more often than other woodland owners because they are used to it.

Weed problems

Major problem weed species are bramble (*Rubus fruticosus* agg.) which is very frequent in conifer stands on eutrophic sites and responds quickly to increased light availability and soil wounding, bracken (*Pteridum aquilinum*), stinging nettle (*Urtica dioica*), sedge (*Carex* sp.) and reed grass (*Calamagrostis* sp.). Traveller's joy (*Clematis vitalba*), purple moor-grass (*Molinia caerulea*), broom (*Cytisus scoparius* ssp. *scoparius*), and invasive alien species such as black cherry (*Prunus serotina*), Himalayan balsam (*Impatiens glandulifera*) and American pokeweed (*Phytolacca acinosa*) are of local importance. However, as clearfelling is avoided, ground vegetation competing with tree regeneration often does not affect the whole stand (Table 5.8).

Table 5.8 | Area (in ha) affected by major weed species. Source: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2005).

Species	Cover > 50 %	Cover 10–50 %	Cover 1–10 %	Missing
Rubus fruticosus agg.	420 647	979 651	2 735 614	6 431 748
Urtica dioica	116 109	392 127	1 603 557	8 455 867
Calamagrostis sp.	226 315	385 388	723 357	9 232 599
Pteridum aquilinum	109 923	195 101	337 122	9 925 514

Treatments and alternatives

Current knowledge

Methods and strategies adopted for managing weeds in German woodlands

The different options for the management of weeds are of varying importance.

Silvicultural systems

The most common method to reduce weed impact is lengthening the regeneration period by keeping at least some overstorey trees over a period of 30 years or more in order to restrict light, water and nutrient availability for weeds. The establishment of pioneer nurse crops such as alder (*Alnus glutinosa*), birch (*Betula pendula*), willow (*Salix* sp.) and aspen (*Populus tremula*) on open field conditions serves the same purpose. These are fast growing species which are adapted to open field conditions and which normally overtop weeds after one year. Thus they do not have to be weeded. After two to three years mid or late successional crop tree species such as European beech (*Fagus sylvatica*), Douglas-fir (*Pseudotsuga menziesii*) and silver fir (*Abies alba*) are planted below the shelter of the nurse crops (Photos 5.1 and 5.2, page 64).

Table 5.9 | Ranking of weed control methods by silvicultural experts of selected federal states: the higher the number of ★ the more important the method (data from a poll in 2007).

Species	Overstorey and retention trees	Mechanical treatment	Chemical treatment	Pioneer nurse crop	Soil cultivation	Mulching
Baden-Württemberg	★★★★★★	★★★★★	★	★★★	★★	★★★★
Bayern	★★★★★★	★★★★	★	★★★★★	★★★	★★
Rheinland-Pfalz	★★★★★★	★★★★★	★	★★★★	★★★	★★
Saarland	★★★★★★	★★★★	★	★★★★★	★★★	★★
Sachsen	★★★★★★	★★★★	★★★	★	★★★★★	★★

Mechanical methods

Weed control by mechanical methods is more frequent than herbicide use. It is used randomly, for example 50 to 100 clusters per ha of around 20 to 40 m^2 diameter in size. Soil cultivation or machine mulching are only of local importance. They are used when thick grass layers permanently hamper natural regeneration or serve as habitats for mice that threaten plantations.

Mulches

Sheet mulches are only used locally because they are too expensive.

Biological weed control

Biological weed control is being tested, for example in northeastern Germany using the fungus *Chondrostereum purpureum* to effect die-off in *Prunus serotina*.

Herbicides

The use of herbicides is cheaper than alternative methods of weed control (Wagner and Jönsson, 2001; Thoroe *et al.*, 2003; Table 5.10). Therefore there is ongoing discussion on whether or not forest owners should be subsidized if they reject the use of herbicides. The main herbicides used in German forestry are given in Table 5.11.

Table 5.10 | Costs of different methods of weed control in € ha^{-1}.

State	Chemical treatment	Mechanical treatment	Mulching	Soil cultivation
Baden-Württemberg	175	570	750	755
Bayern		400–1000	400	250–450
Berlin		1000		
Sachsen	582	482–744		755–1158
Niedersachsen	171	355	300	700
Rheinland-Pfalz		450		
Saarland		120		

Table 5.11 | Main herbicides used in German forestry.

Herbicide	Number of forest approvals for the German market
Glyphosate	22
Glufosinate ammonium	2
Clethodim	2
Isoxaben	1
Fluazifop-P-butyl	1

Ongoing research

Current research is focused on the impact of invasive alien species such as Himalayan balsam (*Impatiens glandulifera*) on establishment and growth of tree regeneration. Another field of research comprises experiments using the fungus *Chondrostereum purpureum* to control black cherry (*Prunus serotina*), which is invading many Scots pine forests. Other investigations concern the impact of grasses on soil water availability.

Future research needs / potential for European collaboration

Future research should focus on the extent to which mutual impact of tree regeneration and weeds is affected by climate change and/or by the ongoing nitrogen deposition. The behaviour of invasive alien species needs to be investigated, and there is an urgent need for cheap and efficient but ecologically acceptable concepts to control bramble. Finally, research into the suitability of direct seeding for the restoration of areas overgrown with grasses would be of great interest.

Barriers to carrying out future research

Progress in research is hampered by a lack of funding.

Ecosystem responses

Current knowledge

There is a huge amount of literature about the impact of weeds on tree regeneration, e.g. Howard and Newton, 1984; Byrne and Wentworth, 1988; Kolb *et al.*, 1989; DeLong, 1991; Comeau *et al.*, 1993; Ammer, 1996; Nilsson *et al.*, 1996; Davis *et al.*, 1998; Harrington and Edwards, 1999; Quicke *et al.*, 1999; Löf, 2000; Rose and Ketchum, 2002; Cole *et al.*, 2003; Coll *et al.*, 2003; Coll *et al.*, 2004; Curt *et al.*, 2005, all indicating that competition causes mortality and limits growth of tree seedlings. However, generalizations are difficult as the impact of a specific weed depends on the site conditions, i.e. availability of resources and the tree species in question. There are gaps in the information about the behaviour of invasive alien weeds and about the predictability of weed interference in a changing climate.

Future research needs / potential for European collaboration

As a priority, joint investigations on the ecology and the competitive effects of problematic species such as bramble and bracken are needed. Based on this knowledge it might be possible to derive models to predict the impact of weeds on tree seedlings in relation to different silvicultural treatments and climate change.

Barriers to carrying out future research

Progress in research is hampered by a lack of funding.

Society and vegetation management

To our knowledge there is no investigation of society's perception of different vegetation management approaches in Germany. Only chemical treatments seem to be problematic for the public. However, as chemical weed control does not now play an important role in Germany, obtaining funding for research into its social acceptability would probably be difficult.

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6 Greece

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Country background

History

The vegetation of the Greek landscape is rich in plant species and very variable in architectural, ecological and life forms. According to Liacos (1980), over the long history of man in the Mediterranean Basin, vegetation has received incessant pressures to open up farm land, to develop pastures, to produce food and fibre, and to ensure fuel and construction materials. These pressures have resulted in alternation, destruction or elimination of vegetation; yet, through the centuries, it has adapted and survived through an equilibrium developed between man and the environment.

Topography and climate

Greece is predominantly mountainous; the altitude ranges from sea level to approximately 3000 m (Mount Olympus), and hills and high mountains break the land surface, usually steep and eroded. Moderate (40–70 %) and steep (>70 %) slopes are dominant and relatively narrow; deeply incised channels characterize the dense drainage system. Heavy rains each year can move large amounts of debris (up to 700 tonnes) and hence soil erosion is a serious problem (Nakos, 1983). The climate is Mediterranean, characterized by long summer droughts with high temperatures, which is ecologically extremely important. Rainfall during the summer months rarely exceeds 15 mm in many areas. The mountainous relief of the country and its proximity to the sea contribute towards a range of conditions from typical Mediterranean to Continental.

Land use	Area (ha)	Percentage (%)
Woodlands	6 513 000	49.3
Grasslands	1 700 000	12.9
Agriculture	3 959 000	30.0
Urban / other	1 024 700	7.8
Total	**13 196 700**	**100.0**

Table 6.1 | Land use in Greece. Source: adapted from Greek Ministry of Agriculture (1992).

Woodland area

Woodlands occupy a large part of the land area of Greece, about 49.3 % of the country's total area (Table 6.1). Grasslands, which are natural ecosystems, are managed with sustainable ecological principles and according to forest law; therefore, in some inventories they are classified as forest land. Also, some wooded plantations which are grown on agricultural land are classified as agriculture land use. Twenty-five per cent of woodlands (Table 6.2) are regarded as productive forests, yielding at least 1 cubic metre of timber per hectare per year. This productivity is low and certainly below their potential, especially for the broadleaved oak forests which are mainly coppice (75 % of the total oak forests covering 23 % of the forest area; Smiris and Dafis, 1988; Scarascia *et al.*, 2000). The remaining forested area (23.9 %) consists of land covered by shrubs and trees mainly in shrubby form. These woodlands do not produce commercial wood products but they have multiple uses as providers of firewood, soil protection, water production, landscape and aesthetic values, wildlife habitat and forage for grazing domesticated animals and wild animals (Liacos, 1982; Greek Ministry of Agriculture, 1992).

Table 6.2 I Type of forest lands in Greece. Source: adapted from Greek Ministry of Agriculture (1992).

	Area (ha)	Percentage (%)
Closed forests	3 359 000	25.4[a]
coniferous	1 430 000	21.9[b]
broadleaved	1 929 000	29.6[b]
Shrublands	3 154 000	23.9[a]
evergreen oaks	460 000	13.3[b]
other species	2 694 000	35.1[b]
Total	**6 513 000**	**49.3[a]**

[a] Per cent (%) of the total area of the country.
[b] Per cent (%) of the total forested area.

The mean growing stock of Greek forests of about 45.2 m^3 ha^{-1} is relatively low (Greek Ministry of Agriculture, 1992) compared to the mean growing stock of other European countries. However, it should be noted that this number does not reveal the real state of Greek forests, as there are many well-organized forest complexes which have been managed for a long time and support stands with a mean growing stock ranging from 350 to 400 m^3 ha^{-1}. The mean growing stock of forests in total has decreased significantly because a high percentage of forests are coppice or over-thinned due mainly to wildfires and human activity. The annual gross increment of the forests is estimated at 4.1 million m^3, while their annual mean mortality is 0.3 million m^3. The mortality of cultivated forests is nearly zero and this can be attributed to improvement of their qualitative composition.

A high percentage (96 %) of woodlands are natural while the remaining 4 % comprises semi-natural and plantations (Table 6.3). Semi-natural woodlands are Aleppo pine (*Pinus halepensis* Mill.) and Calabrian pine (*Pinus brutia* Ten.) reforestations, as well as black pine (*Pinus nigra* Arn.) and fir (*Abies* spp.). Woodland plantations are mainly poplar (*Populus* sp.).

Table 6.3 I Natural and plantation woodland in Greece.

Land use	Area (ha)	Percentage (%)
Natural forest	6 250 000	95.8
Man-made	224 000	3.4
Other semi-natural	39 000	0.6
Secondary and plantation woodland	9 600	0.2

Species composition

The whole of Greece is classified as a Mediterranean region with a prolonged drought during summer. There are, however, variations among geographic areas (e.g. north–south or mainland–island) and among zones of the same area with different altitude (e.g. low plain, sub-mountainous and mountainous). This climatic variation is manifested by different ecological zones consisting of different vegetation types. These range from the thermo-mediterranean formations of the Oleo-Ceratonion sub-type (such as the most xerothermophilous forests in the southern limit of the island of Crete) to the most humid-cold formation of mid-European type of *Pinus sylvestris* L. and *Picea abies* Karst. in the northern limit of Greece (Table 6.4).

Table 6.4 I Ecological zones and important forest species of Greece (Mavromatis, 1980; Nakos, 1983).

State	Area (ha)	Percentage (%)
Mountainous zone		
Fir *(Abies* sp.)	325 000	12.9
Black pine *(Pinus nigra)*	137 000	5.5
Other conifers	21 000	0.8
Beech *(Fagus* sp.)	219 000	8.8
Sub-mediterranean zone		
Deciduous oaks *(Quercus* sp.)	748 000	29.8
Chestnut *(Castanea* sp.)	23 000	1.2
Others	78 000	2.8
Mediterranean zone		
Aleppo pine *(Pinus halepensis)*	342 000	13.6
Calabrian pine *(Pinus brutia)*	133 000	5.3
Broadleaved evergreen *(maquis)*	478 000	18.9
Others	8 000	0.3

Ownership

The majority of forest land in Greece is state owned (74.1 %), 9 % is communal, while the remaining 16.9 % is privately owned by monasteries, individuals, groups or various organizations and foundations.

Silvicultural and management systems

Silvicultural and management practices vary according to forest type. In general, management practices in Mediterranean forests have two basic principles: the maintenance of closed stands and the promotion of rich regeneration. This management aims to prevent the establishment of undergrowth vegetation and to ensure the following: natural pruning of trees, decomposition of litter, natural regeneration, straight trunks, a final stand with the best individual trees, regular growth of elite trees, and thin branching. However, these classical silvicultural principles do not seem to be justified for aleppo and calabrian forests and a large proportion of deciduous oak forests. For example, under Mediterranean conditions the forest stands of the light demanding coniferous species offer little shade. Even under high canopy cover (>0.1) undergrowth vegetation grows abundantly, natural pruning is practically unfeasible, litter decomposition is slow and natural regeneration is a futile expectation. When seeds do germinate, the young seedlings either cannot reach the mineral soil because of the thick litter layer, or die due to the severe competition with dense undergrowth vegetation for water and/or light.

The management of degraded deciduous oak forests in the Mediterranean basin is based on a coppicing cycle of 15–30 years and follows the traditional economy of Mediterranean regions by providing firewood, charcoal, by-products such as tannin and by offering a grazing area for domestic and wild animals (Dafis, 1966; Liacos, 1980; Debussche *et al.*, 2001). According to Dafis (1966), the deciduous oak forests in Greece are classified into six site classes, of which only the first two and part of the third may maintain economically productive stands. In an attempt to increase the productivity of the remaining sites, it has been proposed that a proportion of them should be converted to high forests after clearcutting and reforestation with coniferous species (Dafis, 1966; Smiris and Dafis, 1988). It is obvious, that another part classifying into four non-productive classes will continue to manage as coppice forests. According to current forest policy, both converted and coppice oak forests have to be protected from grazing animals for up to 10 years. However, reforestation efforts on converted oak forests have failed, either because oak sprouts and spontaneous herbaceous species prevented coniferous growth or unsuitable coniferous species were used (Liacos, 1980). Moreover, coppice oak forests are grazed during the vulnerable establishment phase (0–5 years for sheep, 0–7 years for cattle and 0–10 years for goats) without any control or grazing management plan.

Herbicide use and comparisons

Currently Greek forest managers do not systematically use herbicides and chemical substances in woodlands with the aim of destroying and removing ‘undesired’ vegetative species. However, according to Kalapanida (Forest Research Institute, personal communication, 2007), during the period 2000–2006, 6600 ha of conifers were treated by Foray (13.2 tonnes) to control caterpillars. Moreover, during 2004, an area of 1000 ha dominated by kermes oak (*Quercus coccifera*) was treated by Agree wp (*B. thurigensis* var. *kurstaki/aizawai*) to control *Lymantria dispar* (gypsy moth). In contrast, there is widespread use of herbicides in agriculture (Table 6.5; data from Plant Protection Institute, Ioannidis, personal communication, 2007).

Table 6.5 | Pesticide usage on different crops in Greece.

Crop	Total crop area (ha)	% Land area	Area treated (ha)	% Area of each crop treated	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides	6 513 000	49.3	–	–	–	–
Forestry insecticides / rodenticides	6 513 000	49.3	6 600	0.1	13.2	0.14
Forestry fungicide	6 513 000	49.3	–	–	–	–
Total forestry pesticides	**6 513 000**	**49.3**	**6 600**	**0.1**	**13.2**	**0.14**
Arable	1 200 000		3 600 000[b]		2350	
Glasshouse	4 000		32 000		64	
Grassland[a]	5 520 000		1 104 000		200	
Nurseries	1 200		8 400		45	
Fruit	1 106 000		3 318 000		4483	
Vegetables	120 000		720 000		890	
Other agricultural	68 000		204 000		138	
Industrial and non-crop	1 640 000		4 920 000		1423	

[a] Grassland related to permanent pasture.
[b] Crops will be treated more than once.

Policy drivers

The forestry policy developed in Greece is to expand forests by reforestation and to protect them against wild fires and other risks. Soil protection, wildlife conservation, rangeland management, production of commercial/industrial wood and an improved economic situation for the people living in mountainous areas are included among national forest policy objectives (Vakrou, 1998). Because forests have suffered serious damage by overgrazing or by clearing to open up grazing lands in the past, grazing animals are currently considered as one of the reasons why fulfilment of forestry policy goals is prevented. However, there is evidence that grazing animals and forest production could be integrated under correct management (Liacos, 1980; Nastis, 1993).

Recently, many Greek forest lands have been declared 'protected', with 320 sites (2.7 million ha) listed in the European Network 'NATURA 2000' and Special Protected Areas (SPAs) which aim to take care of wild and vulnerable species of flora and fauna.

Weed problems

Mediterranean pine forests

Light demanding coniferous species (Table 6.2) constitute the most typical forests in the Mediterranean zone and occupy a large proportion of Greece's forest lands. The most common species are Aleppo and Calabrian pines which even after canopy closure support appreciable understorey vegetation (Photo 6.1, page 64). This vegetation, composed of shrubby and herbaceous species, competes strongly with young trees for soil water, which is the limiting factor for plant growth in Mediterranean climate areas (Spanos *et al.*, 2000). In addition herbaceous and woody understorey plants accumulate as 'fuel' at ground level which creates a fire danger due to its flammability during summer.

Plantations

As already mentioned, one of the goals of Greek forest policy is to increase the production of industrial wood. This will be achieved in part by reforestation and in part by improvement of productivity of existing forests. However, most of the time reforestation is carried out on grasslands or shrublands that are typical grazing or browsing areas. These plantations are protected against grazing animals, resulting in depression of livestock production and in the rise of conflicts between animal breeders and forest authorities. In addition, as in the pine forests, these plantations are threatened by frequent and devastating wild fires because herbaceous species grow abundantly at ground level and then turn into dry, flammable vegetation during summer.

Up to now, coniferous trees have played an important role in reforestation in Greece, because of their easy and rapid establishment in arid sites. Conifers are well adapted to the poor water and nutrient resources available on the drier and rocky slopes used chiefly for afforestation. However, Greek forest policy on reforestation has recently changed, and broadleaved species are now preferred to conifers in many arid areas, since the former are more resistant to wildfires compared to the latter; but they are more water demanding.

Oak forests

Ten different oaks grow as native species in Greek forests and cover about 22.6 % of the total area. The dominant oak species in Greek Mediterranean ecosystems grow in different climatic and ecological zones. Most are now coppice oak forests and a large area is covered by evergreen broadleaved species. High (from seed) oak forests (mainly *Quercus frainetto* Ten., *Q. pubescens Willd*., *Q. cerris* L. and *Q. petraea* Liebl.) cover 239 000 ha, middle oak forests cover 127 000 ha, and 1 105 350 ha are covered by coppice and 460 000 ha by shrubland oak evergreen species (*Quercus coccifera* L. and *Q. ilex* L.).

As previously mentioned, the deciduous oak forests in Greece have been classified into six site classes (Dafis, 1966), of which only the first two and a part of the third may maintain economically productive stands. In an attempt to increase the productivity of the remaining sites, it was proposed (Dafis, 1966) that they should be converted to high forests after clearcutting and reforestation with coniferous species. The protection of these forests against grazing is considered as a necessary management tool. However, reforestation has failed because oak sprouts (in this case considered as weeds) and spontaneous herbaceous species have prevented good coniferous growth or the best adapted coniferous species were not planted (Liacos, 1980).

Shrublands

Shrublands (Table 6.2) dominate the landscape of the low elevation zone of Greece, covering 13 % of its total forested area. They are degraded former productive high forests, mainly deciduous oaks; their most profitable use at present is for grazing by domestic animals. The current management goal for these shrublands is to create a combination of kermes oak pastures of varying cover (mosaic of vegetation types) over the total area (Papachritou and Nastis, 1993a). This improved form of management aims to provide various products and services such as forage, firewood, landscape and recreation, soil protection and water conservation. The first step in this management regime is to open up the shrub canopy via prescribed burning, manual thinning, herbicides or mechanical means. However, opening up shrublands raises a number of questions. Will woody vegetation be removed until the desired percentage of shrub cover is achieved or should herbivore grazing for the removal of non-preferred woody species also be considered?

Treatments and alternatives

Current knowledge

Methods and strategies adopted for managing weeds in Greek woodlands

Silvicultural systems

Mediterranean pine forests. The management goal for these forests is to carry reduced undergrowth vegetation. From a silvicultural point of view two methods could be used: manual and/or mechanical removal. A practical suggestion is to use mechanical means in sites with deep soil and gentle slopes and leave manual cleaning for the less productive and steeper slopes. Such a practice could ensure increased production from the good sites without jeopardizing soil loss through erosion, thus making good use of ecosystem production.

Oak forests. Oak forests and some secondary species such as hornbeam (*Carpinus* sp.) and ash (*Fraxinus* sp.) have suffered more than any other type of Mediterranean forest from grazing and uncontrolled felling, resulting in their deterioration. A conversion to conifer forests by artificial planting was therefore proposed for these degraded forests; and grazing is not allowed for 5 to 10 years after planting, depending on animal species. However, competition from vigorously growing oak sprouts during that period creates real survival problems for conifers. Protection against grazing is also used after clearcut exploitation in coppice oak forests, in which the goal is to convert them to high oak or conifer forests.

Shrublands. These woodlands occupy a large part of the land area of countries around the Mediterranean basin, and the kermes oak, a sclerophyllous shrub, is the dominant species (Le Houerou, 1980; Le Houerou, 1993). In Greece, the kermes oak shrublands are browsed rangelands, covering more than 0.4 million ha (Liacos, 1982). They are usually managed as grazing forest lands and are vitally important in small ruminant agriculture. Research projects have been carried out on the effects of vegetation distribution (i.e. mosaic of shrubs and open pasture) and the effects of seasonal changes in shrubland characteristics on the diet selection of animals (Papanastasis and Liacos, 1983; Papachristou and Nastis, 1993a, 1993b). They concluded that dense shrublands provide limited amounts of usable forage because they are difficult to penetrate compared to the more open shrublands that are preferred for grazing. However, absence of the shrub component in the semi-arid regions results in poor forage quality when herbaceous species are mature. Based on findings of these studies, it has been suggested that the shrubby component of shrublands should be maintained at 50 % of the total land cover as this produced the best overall foraging conditions and thus best animal performance.

To achieve this goal a series of management techniques can be used:

- *Prescribed burning* and sowing with herbaceous species, i.e. grasses and legumes.
- *Thinning accompanied by topping:* this includes removing the types of kermes oak with low preference index and reducing the shrub topping to the accessible goat height, i.e. approximately 0.8 m.
- *Thinning without topping:* a number of kermes oak sprouts spreading over the whole shrubland area are left to grow as trees while the remainder are thinned by manual means or eliminated by prescribed burning.
- *Clearcutting:* elimination of woody vegetation by manual or mechanical means followed by optional root ploughing and seeding with grasses and legumes.
- *Slashing:* woody plants are slashed by a roller chopper, giving a relatively open vegetation form with a shrub height of 20–40 cm above ground level.

Mechanical methods

In Greece, mechanical methods have been used in densely wooded shrublands with the aim of increasing and diversifying forage production, as well as creating a heterogeneous landscape. For example, Papachristou (1997) and Papachristou *et al.* (1997) tested the techniques of clearcutting and slashing followed by seeding with grasses and legumes and compared them with untreated shrublands of medium density (56 % shrub cover). Economics are critical in the assessment of the effectiveness of mechanical means to control the woody component of shrublands for sustained high yields of forage and the extent to which it should be applied. Rotary slashing of shrubs is less expensive than clearing with a bulldozer; it is also more ecological and does not disturb the soil (Papanastasis *et al.*, 1991). However, the disadvantage is that woody species recover soon after the treatment. There is therefore a trade-off between effectiveness and cost of each method. A practical suggestion is to employ shrub bulldozing on sites with deep soil and gentle slopes and leave rotary slashing for the less productive and steeper slopes. Such a practice could ensure an increased production from the good sites without jeopardizing soil loss through erosion, thus making good use of ecosystem production. In the meantime other methods (e.g. controlled burning or re-cutting) need to be tested as a means of effectively controlling sprouting woody species, including skilful grazing management.

Cultivation and mulches

No information is available on cultivation or mulches.

Biological weed control (grazing)

It is true that forest lands deteriorate when grazing is uncontrolled. Yet these lands may be integrated with livestock husbandry when forest management is appropriate to the particular bioclimatic and socio-economic conditions related to each forest type and area (Liacos, 1980). Forage production under the tree canopy and the reaction of forest trees to grazing vary according to forest type and tree species. Liacos (1980) classified forest lands according to plant ecology and the grazing problems within them (Table 6.6); he suggested a realistic model for the coexistence of grazing animals with some forest lands. More specifically, Liacos suggested that grazing activity within forests of light demanding coniferous species such as aleppo pine and calabrian pine, deciduous oak and hornbeam and ash species is justified as a silvicultural tool which favours the growth of trees. Grazing has to be excluded from fir, black pine, beech and sweet chestnut forests because of disastrous consequences. The most suitable forest lands from the standpoint of livestock production are those covered by evergreen shrub vegetation with kermes oak as dominant species.

Forest land groups	Area (ha)
Light demanding coniferous species	528 000
Deciduous oak species	1 034 000
Mediterranean firs and black pines	509 000
Beech and chestnut species	262 000
Shrublands	743 000
Others	5 000

Table 6.6 | Classification of Greek forest lands according to species ecology and the similarity of grazing problems. Adapted from Liacos (1980).

Experimental data (Liacos, 1977; Nastis *et al.*, 1991) indicate that small ruminant (sheep, goats) grazing has a significant impact on understorey vegetation of Calabrian pine forests, resulting in a decrease in fire intensity and frequency. The number of new pine seedlings is also increased because they are favoured by the reduction of ground vegetation, i.e. forage. It has also been reported that grazing animals reduce only the herbaceous and leafy material while the woody fuel accumulation is not affected (Nastis, 1993). Likewise, Braziotis and Papanastasis (1995), who studied the herbage production on the understorey of low density (1000 trees ha^{-1}) 20-year-old maritime pine (*Pinus pinaster* Aiton.) stands found that it was significantly reduced as a result of the grazing. However, Koukoura *et al.* (1993), investigating the effects of the combination of prescribed burning and goats grazing on the pine regeneration of a 55-year-old Calabrian pine stand, found that regeneration was favoured by the burning and protection from grazing. The grazing, however, reduced the height of the herbaceous plants (8.1 cm with grazing versus 15.1 cm if protected).

Data from Papanastasis (1982) also indicate that plantations of black pine and maritime pine over 5 years old can be effectively grazed by cattle under a controlled grazing system. An interesting finding of this study was that the herbaceous vegetation on the understorey was significantly reduced due to grazing while no damage was recorded to pine trees. Cattle did not show any interest in tree foliage even when the herbaceous material was mature and depleted in nutrients. The reduction of herbaceous material resulted in a decrease in water competition thus favouring tree growth and reducing wild fire hazard.

Recently Papachristou *et al*. (2005b) studied the integration of cattle and goats grazing in oak forests and whether the oak sprouts and herbaceous material could be controlled by grazing. Although cattle and goats seemed to have a similar foraging pattern with respect to the time spent per foraging station and their bite rate, they eat in different ways. Cattle eat only the herbaceous vegetation, whereas goats eat a mixture of vegetation categories, which consist of both woody and herbaceous species; thus any negative effect of grazing on oak sprouts growth would probably be due to goats. They also concluded that it may not be necessary to exclude cattle for 7 years from such forests. This would favour oak growth, since cattle may control the undergrowth vegetation, i.e. herbs. However, goats can be used as silvicultural means only in the converted oak forests; here they can reduce the competition between planted trees and native vegetation, i.e. oak and other woody species sprouts and herbaceous vegetation.

The use of grazing as a management tool in kermes oak forest lands seems to be appropriate and the most profitable for the control of undesirable vegetation (Photo 6.2, page 64). In the Mediterranean region a series of such grazing management schemes was applied by modifying the seasonal growth pattern of the dominant woody species in Mediterranean shrublands (i.e. kermes oak), which produces new growth in spring and again in autumn with the first rains after the dry summer (see Papachristou *et al.*, 2005a).

Barriers to adopting alternative methods

The work discussed above has concentrated on how grazing could be integrated with forest management practices and become an alternative method for weed control in forest lands. However, we have taken into account that the integration of forestry and livestock may also be favourable to the economy of the resident population. This integration in the remote and more disadvantaged regions of the country will encourage the population to stay there, thereby maintaining the social fabric of these regions. It is known that the abandonment of animal grazing and disappearance of extensive husbandry systems have led to a substantial increase in woody cover, through natural recolonization (Papanastasis, 1999). This process may have numerous ecological and biological consequences; reconsideration of the policy with respect to integration of grazing in forest management practices is therefore needed.

It is obvious that knowledge gaps about how herbivores interact with the forest ecosystem (plants, soil, water, etc.) form a barrier, and we need more information before any grazing prescription for Mediterranean forests can be formulated.

Ongoing research

Current research includes work on plant herbivore interactions with the aim of using this knowledge as a tool to enhance and maintain the biodiversity of landscapes. An integrated understanding of how plant biochemical diversity influences foraging by large mammalian herbivores at the landscape level and what bearing this has, in turn, on plant community dynamics will have profound implications for enhancing biodiversity of landscapes. Knowledge of foraging behaviour can markedly influence and enhance ecological relationships among people, herbivores, plants and landscapes, and, in the process, improve the quality of life for land and livestock managers as well as the integrity of the environment.

Future research needs/potential for European collaboration

The potential management implications associated with integration of grazing into woodlands suggests that the results of experiments could be incorporated into a framework of plant responses to herbivory to better determine the efficacy of grazing systems as a management tool. The following areas of knowledge need strengthening:

1. The response of trees to herbivory and other forms of structural damage.

2. The timing of responses to herbivory and other forms of structural damage.

The following future research is therefore required:

- Controlled experiments quantifying changes in morphology and chemistry in forest trees in response to herbivory and other forms of structural damage.
- Development of computer simulation models of woodland response to herbivory that can be used as a management tool to determine the optimal grazing system for woodlands.
- Field experiments on grazing management practices for herbivores in woodlands to test the predictive power of the simulation models.

Barriers to carrying out future research

Lack of funding may hamper future research.

Ecosystem responses

Current knowledge

Effects of weeds on trees

In Greece the areas of concern are the effects of competition from undesirable vegetation on soil moisture and nutrients, and to a lesser extent light and the physical smothering of seedlings. Undesirable vegetation is defined according to the management purpose of a specific forest type. For example:

- in pine forests it is the herbaceous and shrubby component of their understorey;
- in coppice oak forests it is the herbaceous vegetation, unwanted oak sprouts and other woody species;
- in forest plantations the undesirable vegetation is the native herbs and woody species which compete with planted forest species;
- in shrublands it is the woody component when it becomes too tall and dense.

Nature and magnitude of effects

Research has shown that effects vary depending on the particular forest type and the management goal.

Ongoing research

The Forest Research Institute in Greece is researching the relative effectiveness of different methods of controlling undesirable vegetation, such as burning, grazing, mechanical means, and their effects on the whole ecosystem.

Future research needs / potential for European collaboration

Examples of requirements for future research in Greece, that may be amenable to European collaboration, include developing new ways to control undesirable vegetation in forest lands, to maintain biodiversity of landscapes and to produce food without fertilizers, hormones and antibiotics. With regard to livestock grazing, while some traditional practices have been detrimental to landscapes ecologically and to people economically, there is a growing appreciation for the value of managed grazing by livestock to enhance landscapes for the benefit of wild and domestic animals and people. We have tried repeatedly to alter landscapes to suit animals, but have done little to breed locally adapted animals suited to landscapes. Nor have we understood how to work with nature to accomplish low-cost ways to manage ever-changing landscapes; clearly new mindsets are needed.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge

No research appears to have been carried out specifically into the social dimensions of vegetation management within woodlands in Greece, although the importance of grazing on forest lands in helping to maintain rural populations has already been noted.

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Czech Republic Photo 1.1 | *Picea abies* saplings planted in the vicinity of a dead trunk, as a protection against weeds and unfavourable climatic conditions.

Czech Republic Photo 1.2 | Manual weed control and consequent slash buring in a clearcut area prior to planting.

Denmark Photo 2.1 | New ways of productive and low-cost vegetation management for forest regeneration and afforestation without using pesticides? Directly sown beech with a poplar nurse crop six growing seasons after establishment on former farmland. Poplar cuttings were planted shortly after beechnuts were sown in May 1999 (the pole is 70 cm tall). Shown at January 2005 the poplar (1.5 x 3 m spacing) was pre-commercially thinned once at that time. Following the last wheat crop in 1998 the area was treated with glyphosate according to common agricultural practice and later deep ploughed (70 cm), and a cover crop of rye was sown in September 1998.

Denmark Photo 2.2 | Christmas trees have a dominant role in Danish forestry. They are probably the most intensive and environmentally impacting forest crop in terms of vegetation management. On this Christmas tree farm in northern Denmark on a wind-exposed site, a cereal crop creates a light shelter for the young Nordmann fir *(Abies nordmanniana).* The crop has been sprayed with both pre-emergent (terbuthylazine) and post-emergent (iodosuforone) herbicides.

Denmark Photo 2.3 | Two-wheeled tractor with flail mower attachment, used for mechanical vegetation management in forests owned by the municipality of Vejle, where herbicide use since 2003 is prohibited through a voluntary agreement.

Finland Photo 3.1 | Forests covering three-quarters of Finland's land area are an important aspect of the Finnish landscape. Agricultural land covers 9% of Finland's land area (Erkki Oksanen).

Finland Photo 3.2 | Over 250 000 ha of arable land has been afforested in Finland. The ground vegetation on arable lands differs completely from that normal forests. The development of ground vegetation after afforestation is fast and vigorous. Grasses and herbs retain their dominant role for a long time after afforestation (Jyrki Hytönen).

Finland Photo 3.3 | Control of woody weeds (140 000 ha in 2006) is typically carried out by brush-cutting saw. In this Scots pine stand brush consisting of mostly birch seedlings has been cut earlier in the season (Nuutti Kiljunen).

France Photo 4.1 | Small mechanical tool for local soil preparation at Koeur (Léon Wehrlen).

France Photo 4.2 | Natural mulches and tree direct seeding at Claye-Souilly (Philippe Balandier).

France Photo 4.3 | Walnut and cover plants at Clermont-Ferrand (Philippe Balandier).

Germany Photo 5.1 | Conversion of a pure Norway spruce stand into a mixed stand by planting European beech in advance. Spruce regeneration is expected naturally. Overstorey trees hamper the establishment of weeds. The time span from the beginning of the underplanting until the harvest of the last spruce varies between 20 and 40 years (depending on the timber market and the stability of the stand). No vegetation management is needed. In addition, the branchiness of the beech saplings is decreased due to reduced light availability.

Germany Photo 5.2 | Former Norway spruce stand destroyed by bark beetles (with remaining hardwoods). If the soils are not too fertile and the browsing pressure is bearable, natural regeneration by early successional species can be expected which quickly cover the site. Target tree species will be planted later. In all other cases immediate planting or direct seeding is recommended in order to avoid costly vegetation management.

Greece Photo 6.1 | Calabrian pine stand with an understorey composed of herbaceous species.

Greece Photo 6.2 | Grazing is an economical way to enhance diversity of dense kermes oak shrubland by creating mosaics of grasses and forbs within the oak stands.

7

Iceland

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Country background

History

Archaeological and geological excavations indicate that Iceland was probably 60 % covered by vegetation and about 30 % by woodlands when the Vikings first arrived in the late 9th century. In Norway or Sweden, where trees were depleted or pastures were overgrazed common farming practice was to leave them and within a few years (or a generation at the most) natural recovery would take place. When the Norse settlers came to Iceland, this practice did not change: their livestock roamed free and birch woodlands were cut for firewood, charcoal and general construction. As the population grew (it was 50 000 at the first census in 1703), the nation's need for wood also grew. Mini ice-ages occurred bringing a crueller climate, and the occasional major volcanic eruption was also life-threatening. With livestock numbers growing to hundreds of thousands by the 18th century, the consumption habits of domestic animals took a devasting toll on the woodlands.

In the 1974 Annals of the Icelandic Forestry Society, Thorarinn Thorarinsson wrote that, over the centuries, 8200 km^2 of woodlands were cut down solely to make charcoal for forging iron and blacksmithing. This meant that by the 1900s Iceland had lost an estimated 97 % of its original forests. Around that time a Danish admiral, Carl Ryder, outraged at the Icelanders' lack of fuelwood, lobbied parliament and managed to obtain funding for tree-planting experiments in Iceland. By 1908, the Icelandic State Forestry was established, and its first task was to fence off the last remaining stands of woodlands. The Forestry Association was founded in 1930, and their objective was to involve the general public in tree-planting. Until the late 1960s, afforestation and forest protection was mainly on public land. A significant change took place in 1967 when the State Forestry provided farmers in eastern Iceland with seedlings to plant on their own land. This idea developed and spread to other regions of the country. Today close to 80 % of the afforestation effort is on private land with state premiums for fencing, site preparation and seedlings (Gunnarsson, 2007). In 2007 approximately 6 million trees were planted in Iceland, 80 % on private land.

Today the objective of afforestation is no longer fuelwood, as most households in Iceland are supplied with geothermal heat, but rather for the purposes of protection, production and recreation with consideration given to public opinion and suitability of the site.

Climate and topography

Iceland is a 103 000 km^2 island in the North Atlantic Ocean between 63 and 66 ˚N. It is warmed by the Gulf Stream, and the climate is humid cold temperate to low arctic with mild winters and cool summers. The weather in Iceland is quite changeable and depends mostly on the tracks of atmospheric depressions that cross the North Atlantic. Precipitation varies between 500 and 2000 mm in lowland areas. The average January temperature in 2006 for Reykjavík was 2.0 °C (-11.4 °C to 9.3 °C) and in July the average temperature was 11.1 °C (4.9 °C to 19.0 °C). In Akureyri in the north, measured average temperature for January was 1.8 °C (-9.3 °C to 11.1 °C) and 10.6 °C (2.3 °C to 22.9 °C) for July (Icelandic Meteorological Office, 2008).

The island is mountainous with lowland areas along the coastline and river plains. It consists mainly of a central volcanic plateau, with elevations from about 700 to 800 m, ringed by mountains, the highest of which is Hvannadalshnúkur (2.119 m) in the Öræfajökull glacier. Iceland is an active volcanic island with frequent volcanic eruptions that produce tephra, and volcanic ash deposits are widespread. Most Icelandic soils are therefore dominated by volcanic ash, with Andosols and Vitrisols the dominant soil types (Arnalds and Óskarsson, 2007).

Forested area

The total area of woodlands in Iceland is around 149 000 hectares, equivalent to 1.5 % of the total land area (Table 7.1). About 40 000 ha consist of exotic species and the balance comprises remnants of native woodlands dominated by downy birch (*Betula pubescens* Ehrh.). Afforestation in Iceland is ongoing with the objective of increasing the woodland cover to 5 % of the land area below 300 metres above sea level. The aim is to reach this goal by 2040 (Regional Afforestation Projects, 2007). This will increase the total wooded areas to about 200 000 ha or 2 % of total land area. Today most of the Icelandic birchwoods are open to grazing and less than 15 % have been enclosed. It is almost impossible to find a woodland untouched by man or his domestic animals but due to reduction in grazing pressure during recent decades, natural birchwoods are likely to thrive, claim new land and further increase the woodland cover of Iceland.

Land use	Area (ha)	Percentage (%)
Woodlands	149 000	1.5
Arable land	100 000	1
Permanent pastures	2 400 000	23
Wasteland (no use)	6 500 000	62
Other	1 351 000	22.5
Total	**15 000 000**	**100**

Table 7.1 I Land use in Iceland.

Species composition

Downy birch *(Betula pubescens)* is the only native species forming woodlands in Iceland. Associated species are willows, rowan and, very rarely, aspen. Iceland lies within the boreal forest zone and the dearth of species is due to its isolation in the middle of the North Atlantic Ocean.

Since the first exotics where introduced to Iceland at the beginning of 20th century, over 100 different species have been tried. In general, forestry in Iceland has been regarded as a large experiment, although the initial trials were rather haphazard. Alaska and the Rocky Mountains of the USA and Canada are the most important sources for pines, spruces and willows, while larch is sought from NW Russia. In spite of the relatively short time since exotics were first planted in Iceland, several of them have been observed to set fertile seed, some more or less annually, and several species have regenerated naturally. The greatest emphasis has been placed on larch, spruces, pines and willows (Figure 7.1).

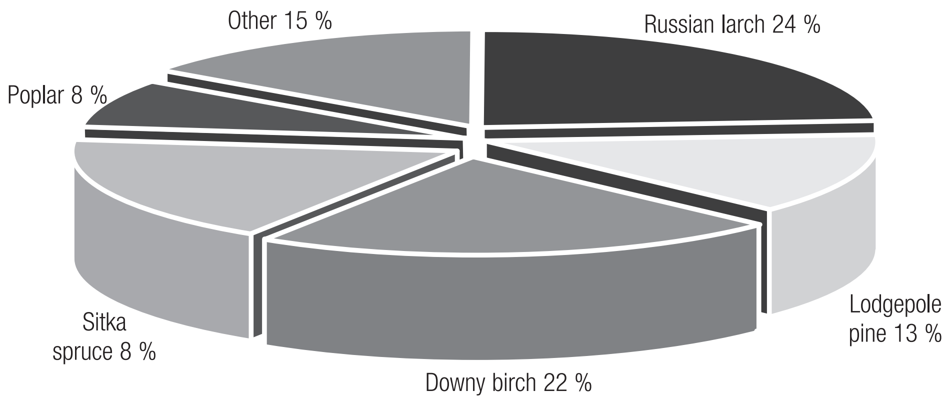

Figure 7.1 I Percentages of the main species planted in Iceland.

Approximately 5 million seedlings have been planted every year for the past 10 years, and given the mean of 2350 plants per ha^{-1} the annual area regenerated for Iceland is little less than 1600 ha yr^{-1}. The average establishment cost with first thinning included is around €3000 ha^{-1} (Snorrasson, 2006). No data are available on the value of average productivity of the country growing stock.

Ownership and subsidy regime

Seventeen per cent of the natural woodlands are on state land; the rest is privately owned. Established plantations are mostly on private land, with former farm land showing the greatest increase in forest cover. The current afforestation work is driven purely by state subsidies and the forestry sector received close to €10 million in 2007. Half of these funds support the regional afforestation projects for privately owned farmland (Regional Afforestation Projects, 2007). The rest of the state funding is budgeted for the Icelandic Forest Service and the Icelandic Soil Conservation Service (Icelandic Forest Service, 2008).

Silvicultural systems

Today, felling is only done in a closed canopy system and in thinning operations.

Herbicide use and comparisons

There has been general agreement to avoid the use of herbicides in plantation establishment where alternative methods could prove successful. No official statistics exist for the use of pesticides in forestry or agriculture, but data have been collected from forest managers. During 2007 total herbicide use in Icelandic forestry was about 30 kg of active ingredient, and this is probably an increase compared to earlier years. Herbicide has been applied in preparation for planting or on spruce plantations where aggressive vegetation competed.

Policy drivers and pesticide regulations

The Administration of Occupational Safety and Health regulates the importation and use of pesticides in Iceland.

Weed problems

Afforestation in grasslands and former hay fields is challenging due to severe competition from existing ground vegetation (Photo 7.1, page 105). As a cover crop for reclamation and afforestation on eroded sites, Alaskan lupin (*Lupinus nootkaensis*) is widely used. Unfortunately, serious competition from the cover crop is often a problem. Other types of weeds have not caused problems in the establishment of plantations In Iceland.

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Icelandic forests

Silvicultural systems

During the first period of the afforestation effort in Iceland, it was common practice to strip-cut natural birch stands and plant exotics in between. This practice has been abandoned altogether and all natural birch land is now protected by law. A cover crop with fast-growing aspen (*Populus trichocarpa*) seems promising for establishing spruce plantations on former farmland.

Mechanical methods

Tractor-pulled scarification machinery is by far the most commonly used supressant of aggressive weeds in plantation establishments. Most-used equipment includes the spot-cultivator and TTS trencher (see Photo 7.2, page 105) and several types of single blade ploughs, used pre-planting.

Cultivation

Cultivation is commonly used in the establishment of Christmas tree plantations but then only in combination with plastic mulches or herbicides. Cultivation on fertile sites tends to magnify the weed problem and increase the risk of frost-heaving.

Mulches

The use of plastic sheet mulches is the main method of shelterbelt establishment in Iceland, and is regarded as having a longer lasting weed supression period than herbicides. In addition the black surface increases temperature around the roots and retains moisture, and generally has an extremely positive effect on the early years of growth. Due to the high cost of soil preparation and the plastic mulch itself, this method is mostly used for establishment of windbreaks on fields.

Biological weed control

There are no recorded experiences of biological weed control in Iceland.

Herbicides

Present-day use of herbicides is limited in plantation establishment, but there has been a trend of increased use in recent years. One explantation for this is failure of many plantations where mechanized methods have been used for weed supression and lack of economical alternatives to herbicide. The most commonly used herbicide is Roundup, where the isopropylamine salt of glyphosate is the active ingredient.

Barriers to adopting alternative methods

The lack of knowledge of alternative methods to herbicide is probably the biggest factor in the trend of increasing herbicide use in Icelandic forestry. No formal research into site preparation methods has been carried out, and most experiments are done on a trial/error basis.

Ongoing research

There is currently no formal research in the field of alternative vegetation management methods in Iceland.

Future research needs/potential for European collaboration

Research and collaboration on topics such as plant size, mulch mechanical site preparation would be useful.

Barriers to carrying out future research

The trend in forest research in Iceland has been away from the field of applied forestry, and more in the direction of highly topical issues such as carbon sequestration, gene conservation and multi-use forestry. Obviously these are very important fields of research with strong funding potential but unfortunately root-level forest research often suffers. Future research could be hampered by the lack of funding, but also by the lack of interest in applied forest science within the research environment.

Ecosystem responses

Current knowledge

Effects of weeds on trees

On grassy sites in Iceland, weeds not only compete with tree seedlings for light and nutritients, but also entangle in the seedlings' branches and flatten them. This problem is further magnified during the winter when snow can weigh down seedlings.

Nature and magnitudes of effects

Little is known of the nature and magnitudes of the effects of weeds on trees in Iceland, but there are clear differences in effects depending on the grass types and sites.

Ongoing research

There are currently no formal research on the effects of weeds on trees and nature and magnitude of such effects.

Future research needs/potential for European collaboration

There is none under discussion at present.

Society and vegetation management

Current knowledge

No formal research has been carried out or is planned in Iceland to investigate the social dimensions of vegetation management within woodlands.

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8 Ireland

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Country background

History

Today Ireland is known as the 'Emerald Isle'. However in Prehistoric times it was renowned as 'the wooded island'. The first trees took root and began to grow just after the first ice age (around 10 000 years ago) as temperatures began to rise. These trees were the dwarf willows and dwarf birch that spread from Scotland. Later the oaks, alder, pine and elm seeded and began to grow. Then, just before the link between Scotland and Antrim was broken, other species such as ash, black poplar, rowan, whitebeam, cherry, holly, juniper and yew took root. These trees came to make up the natural forest of that time (Fitzpatrick, 1985).

The first inhabitants arrived around 4500 years ago, and soon after a gradual clearance of this woodland began to take place in favour of agriculture and for use in the construction of buildings and boats. By the end of the 19th century woodland cover in Ireland had been reduced to only 1 % of the national land area, approximately 69 000 hectares (Forest Service, 2007).

Enter the state and a programme of afforestation began. During the period 1900–1975 forestry was carried out almost exclusively by the state and by 1985 almost 420 000 ha of woodland covered Ireland. Then in the mid-1980s EU-funded grant schemes along with incentives and premiums from the state were introduced to encourage private land owners, mainly farmers, to become involved in forestry. This resulted in the woodland area in Ireland increasing to approximately 698 000 ha according to the latest National Forest Inventory (Forest Service, 2007: Table 8.1). This is divided between 43 % private ownership and 57 % state forestry (Forest Ervice, 2007 Table 8.2).

Land use	Area (ha)	Percentage (%)
Forest	625 750	9.0
Forest open area	72 100	1.0
Non-forest	6 278 270	90.0
Total	**6 976 110**	**100**

Table 8.1 I Land use type in the Republic of Ireland (Forest Service, 2007).

Land use	Area (ha)	Percentage (%)
Public	397 460	57.0
Private (grant aided)	212 200	30.4
Private (other)	88 190	12.6
Total	**697 850**	**100**

Table 8.2 I Present percentage forest cover in Ireland showing the breakdown between private and public ownership (Forest Service, 2007).

Since the early 1900s forestry in Ireland has mainly been driven by the effort to increase the percentage land cover and to decrease dependence on wood imports. However in the past decade there has been a large shift away from forestry being just a wood producing industry to its development as a multi-use resource, i.e. producing wood but at the same time providing a resource for alternative forest products, sites to promote conservation of biological diversity and also as a major provider of recreation.

Topography and climate

The topography of Ireland features a hilly, central lowland composed of limestone rock surrounded by a broken border of coastal mountains. The geological structure of these mountain ranges varies greatly. The southern mountain ridges are composed of old, red sandstone separated by limestone river valleys which tend to run in an east–west direction. In the mountains of the west and northwest (Galway, Mayo and Donegal), as well as in Counties Down and Wicklow on the east coast, granite rock predominates. A basalt plateau covers much of the northeast of the country while the west of the country has extensive areas of blanket bog.

The central plain, broken in places by low hills, is extensively covered with glacial deposits of clay and sand. It has considerable areas of bog and numerous lakes. The island has seen at least two general glaciations. Everywhere ice-smoothed rock, mountain lakes, glacial valleys and deposits of sand, gravel and clay mark the passage of the ice (Mitchell and Ryan, 1997).

The Atlantic Ocean is the dominant influence on Ireland's climate. Consequently, Ireland does not suffer from the extremes of temperature experienced by many other countries at similar latitude. Average annual temperature is about 9 °C. In the middle and east temperatures tend to be somewhat more extreme than in other parts of the country. For example, summer mean daily maximum is about 19 °C and winter mean daily minimum is about 2.5 °C in these areas.

Mean annual wind speed varies between about 4 m s^{-1} in the east midlands and 7 m s^{-1} in the northwest. Strong winds tend to be more frequent in winter (Photo 8.1) than in summer. Sunshine duration is highest in the southeast of the country. Average rainfall varies between about 800 and 2800 mm. With prevailing southwesterly winds dominating, rainfall figures are highest in the northwest, west and southwest of the country, especially over the higher ground. The annual number of days with more than 1 mm of rain varies between about 150 in the drier parts and over 200 in the wetter parts of the country (Met Eireann, 2008).

Woodland area

In Ireland today woodlands occupy 10 % of the total land area or, as previously mentioned, approximately 698 000 ha; 13 % of the forest estate today is classified as semi-natural woodland, 85 % is plantation forestry with the remaining 2 % temporarily unstocked (Table 8.3). The annual regenerated or reafforested area ranges from 7000 to 8000 ha with an average establishment cost of between €2500 and €7100 ha^{-1}.

Forest type	Area (ha)	Percentage (%)
Afforestation	406 720	58.3
Reforestation	126 060	18.1
Semi-natural woodland	81 750	11.7
Forest open areas	72 100	10.3
Temporarily unstocked	11 220	1.6
Total	**697 850**	**100**

Table 8.3 I Forest types in Ireland (Forest Service, 2007).

Species composition

The woodlands of Ireland are composed of approximately 74 % conifer and 24 % broadleaves (Table 8.4). The main coniferous species are Sitka spruce (*Picea sitchensis*, 52 %), Norway spruce (*Picea abies*, 4 %), larches (*Larix* spp., 3.7 %), Scots pine (*Pinus sylvestris*, 1.2 %) and other pines (10 %). The broadleaved element is composed of birch (*Betula* spp., 4.7 %), ash (*Fraxinus excelsior*, 3.1 %) and oaks (*Quercus* spp., 2.3 %). The full species composition can be seen in Table 8.5.

Species type	Area (ha)	Percentage (%)
Conifer	462 580	73.9
Broadleaf	151 950	24.3
Temporarily unstocked	11 220	1.8
Total	**625 750**	**100**

Table 8.4 I Breakdown of species type in Irish forestry (Forest Service, 2007).

Table 8.5 | Species composition in Irish forestry (Forest Service, 2007).

Species	Area (ha)	Percentage (%)
Sitka spruce *Picea sitchensis*	327 830	52.5
Norway spruce *Picea abies*	25 960	4.1
Scots pine *Pinus sylvestris*	7 340	1.2
Other pine spp.	63 610	10.2
Douglas fir *Pseudotsuga menziesii*	10 200	1.6
Larches *Larix* spp.	22 960	3.7
Other conifers	4 680	0.7
Sessile and pedunculate oak *Quercus petraea and Q. robur*	14 630	2.3
Beech *Fagus sylvatica*	8 710	1.4
Ash *Fraxinus excelsior*	19 160	3.1
Sycamore *Acer pseudoplatanus*	8 060	1.3
Birches *Betula* spp.	29 700	4.7
Alders *Alnus* spp.	11 500	1.8
Other long-living broadleaves	9 550	1.5
Other short-living broadleaves	50 640	8.1
Temporarily unstocked	11 220	1.8
Total	**625 750**	**100**

Silvicultural systems

Clearfell and replant are the predominant systems used in Irish forestry. However other systems such as natural regeneration and continuous cover forestry (Mason *et al.*, 1999) are starting to become important.

Herbicide use

Herbicide use for vegetation management in forestry is the most cost-effective method available to the woodland manager today. However, economic pressure coupled with concern for the environment has probably led to small decreases in herbicide use in forestry in Ireland. Figures from 2006 show that the annual estimated use is 4101 kg of active ingredient for approximately 10% of the land area (Table 8.6).

Table 8.6 | Herbicide usage on some crops in Ireland.

Crop	Total crop area (ha)	% Land area	Area treated (ha)	% Area of each crop treated	Active ingredient used (kg)
Forestry [a]	697 840	10.0	19 000 [c]	0.3	4101 [e]
Arable crops [b]	387 335	5.5	1 074 171	277.0 [d]	663 238
Grassland and fodder crops [b]	4 349 212	62.3	405 469	9.3	489 521

[a] Forestry statistics sourced from National Forest Inventory (2007) and Coillte Teoranta (Personal communication, 2007).
[b] Agriculture statistics sourced from Pesticide usage surveys – 2003 and 2004 (Pesticide Control Service; 2003; 2004).
[c] Estimate based on average of forest area under 5 years old; part will be treated, but some parts will be treated more than once.
[d] Some areas treated more than once.
[e] Estimated total forestry usage, based on public forests as 57 % of total.

Policy

In both forestry and agriculture, weed control through chemical herbicides can create spray drift hazards and adversely affect the environment. In addition pesticide residues (herbicides) in food commodities can directly or indirectly affect human health.

Increased environmental awareness, coupled with the advent of sustainable forest management and the certification process, has also prompted public and industry concern over pesticide use in the forest. Unfortunately, adequate alternatives to herbicides do not currently exist for most of Europe's forest conditions. Furthermore, abrupt reductions in herbicide use occurring as a result of the implementation of Directive 91/414/EEC, without the knowledge or technology to implement effective alternatives, will severely threaten our ability to protect regenerating forest and meet future wood supply needs. The proposed European Union Thematic Strategy on the Sustainable Use of Pesticides (which calls for the promotion of low pesticide input farming and the development of integrated pest management strategies) coupled with The European Union European Forest Action Plan (which calls for enhanced protection of EU forests from biotic agents, enacted for example through research activity under the Seventh Framework Programme) should also act as an incentive to member states to investigate alternative weed control methods.

Main Irish weed problems

In Ireland, because the weather is so conducive to plant growth, any tree planted has to contend with a diverse number of weeds. These include both grasses and herbaceous weeds that are the main competitors on farm forest sites. On restock sites, along with the problems caused by herbaceous weeds and grasses, there are the woody weeds such as bramble (*Rubus fructicosa*), gorse (*Ulex* spp.) and heather (*Calluna vulgaris*). There is increasing concern also about the problems being caused by alien invasive weeds such as rhododendron (*Rhododendron ponticum*) and Japanese knotweed (*Fallopia japonica*), not only to the trees but also to the biodiversity of our woodlands.

Treatments and alternatives

Current knowledge

Methods / strategies adopted for managing weeds in Irish forests

Silvicultural systems

With the advent of new silvicultural management systems such as continuous cover forestry and also initiatives such as Native Woodland and Neighbourhood Schemes in Ireland, the thinking was that these systems would not require as much vegetation management as the older systems such as clearfelling and replanting. The reasoning behind this is that there will always be some canopy cover on the site and this shade cover should reduce the growth of competing weeds. However, this does not always occur because weeds by their nature will exploit any bare ground that becomes available and has sufficient light, and thus often compete with the planted or naturally regenerated tree seedlings despite an overstorey of trees being retained. Also invasive species such as rhododendron still need to be controlled to prevent a reduction in biodiversity.

Mechanical methods

Mechanical methods are rarely used in Ireland as labour costs are prohibitively high. However, in the past it was common practice to trample weeds around the base of trees, and in forest nurseries students were employed to pull weeds.

Cultivation

In general cultivation is used for preparation of the microsite for the tree seedling. However, with some cultivation practices such as mounding there is the added bonus of some weed control for a growing season or more on some sites (Photo 8.2), but generally in Ireland herbicides are used in tandem with the cultivation technique practised.

Mulches

Very little mulching is carried out in Ireland at present. A study of the use of mulch mats in Irish forestry was recently completed (McCarthy *et al.*, 2007; Photo 8.3) and although the mats compared favourably with chemical control in controlling the weeds the cost of installation can be very high. Biodegradable mulch mats have also been used on some sites.

Biological weed control

There have been some successes with using Shropshire sheep to control weeds (Have, 2002) in forestry in Ireland, however in general the use of host-specific biological controls has not been used.

Herbicides

The mainstay of weed management in Ireland is herbicides. The main herbicides used in Irish forestry are given in Table 8.7.

Herbicide		Total kg a.i. [a]
Active ingredient (a.i.)	Product(s)	
Glyphosate	Roundup, Roundup Biactive and No Mix	2523
Atrazine	Atrazine	877
Triclopyr	Garlon	536
Asulam	Asulox	105
Propyzamide	Kerb Flo	35
Imazapyr	Arsenal	25

[a] Estimated usage only, based on state forests as 57 % of the total in 2006. Imazapyr is no longer approved, and atrazine approval was revoked at the end of 2007.

Table 8.7 I Herbicides used in Irish forests in 2006.

Barriers to adopting alternative methods

The biggest barrier to adopting alternative methods of vegetation management in Ireland is economics. Even though EU policy coupled with the certification process is driving the reduction in herbicide use, practitioners are very slow to adopt alternatives. Generally this is due to lack of in-depth research and information on the alternatives. In cases where there is information, economics is the key, as the alternative is generally much more expensive (McCarthy *et al.*, 2007; Willoughby *et al.*, 2004). Research programmes have to be put in place to address this problem not only in Ireland but also in Europe.

Ongoing research

Presently research is being carried out into the potential for control of rhododendron using mycoherbicides (Green, 2003) and also into future problems that may arise from invasive weeds in Irish forestry.

Future research needs / potential for European collaboration

Future research needs in this area in Ireland would be similar to some other European countries: direct seeding, cover crops, biodegradable mulches and control of invasive species (McCarthy and McCarthy, 2005).

Barriers to carrying out future research

In general future research is dependent on adequate funding. Unless mechanisms such as The Seventh Framework Programme propose activities in vegetation management it will be difficult to fund large-scale pan-European projects.

Ecosystem responses

Current knowledge

Effects of weeds on trees

In Ireland, as in the UK, the main concern with weed competition is the effect on soil moisture and nutrients (Davies, 1987). Generally these effects are seen in the early survival and growth of seedlings. However due to the large variation in sites, soils and weeds associated with them, the effects will also show variation.

Impact of control methods

In terms of hard facts concerning the impact of control methods on ecosystems there is no single piece of work but small studies have been carried out on these effects. The best example of this type of collated research/information is to be found in the British Forestry Commission's publication: *Reducing pesticide use in forestry* (Willoughby *et al.*, 2004).

Ongoing research

At the moment the only ongoing research in this area concerns the ecophysiology and control of rhododendron.

Future research needs / potential for European collaboration

Future research needs in this area should be on a pan-European scale, looking at gaining a better understanding of the ecophysiology of the weeds themselves, which may help in identifying alternative methods of controlling them.

Barriers to carrying out future research

Again, funding will be the key to future research.

Society and vegetation management

Current knowledge and ongoing research

Little or no research has been carried out into the public perceptions of vegetation management in Ireland.

Future research needs

With the advent of forests as multi-use resources there has been a big increase in the utilization of forest and woodlands by the public for recreational purposes and thus there is a need to investigate public perception of vegetation management practices in Ireland.

Barriers to carrying out future research

Funding again will be the problem, together with personnel/researchers to carry out the work.

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9

Italy

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Country background

History

Italian forests began to expand around 8000 BC, at the end of the last glaciation. First to increase were coniferous species, then broadleaved, covering almost all the country. Around 300 BC deforestation had already begun, and during Roman times the forested area was considerably reduced due to the expansion of agriculture and the use of wood for heating and ship construction. Throughout the Middle Ages the trend reversed, with an increase in the wooded land; in some areas the monastic orders began to protect the forests under their control and managed the resources (timber, honey, other non-wood products) in rational ways, trying to integrate them with the agricultural activities. Some of these ancient forested areas are almost intact, now mainly administered by the State.

Forests in Italy are mainly concentrated in hilly and mountainous areas (Pettenella *et al.*, 2005) and more than 70 % of the total forested surface is located below 1000 m a.s.l. After World War II forests underwent a rapid natural expansion as a result of urbanization processes and related migratory fluxes of populations from rural marginal areas. Formerly cultivated land, pastures and meadows were rapidly colonized by shrubs and trees. The forest expansion rate is still high, about 0.3 % per year during 1990–2000, compared with a mean European value of about 0.1 %. In contrast, in lowland and productive areas, woodland extension is very limited and stable, accounting for about 2 % of the land area.

The concept of reforestation has changed during recent decades. In the period between World Wars I and II, several forest stands were replanted for various reasons. First there was a need to increase the forest area which had become impoverished due to over-harvesting to meet firewood and construction wood demands; secondly was the need to prevent hydrogeological risks in mountain areas, particularly sediment production, hillslope hydrogeology, debris and mud flow dynamics, alluvial fans and piedmont risks issues, which are more frequent in regions lying along or near the foot of a mountain range. Thirdly, for occupational reasons, to create woodland areas for people to live and work in. Some of this reforestation was carried out with very few and sometimes inappropriate species (mainly conifers used outside their 'natural habitat'), planting was too dense and often only one species was used such as Austrian pine *(Pinus nigra)* and Aleppo pine *(Pinus halepensis)*. Excessive dense coniferous forests resulted, mainly because of lack of management, with unstable trees, total lack of regeneration and soil acidification.

In the past 30 years, with the increases in management costs, the changing interest towards reforestation and other reasons also related to socio-economic changes (the competitive prices of imported timber, urbanization phenomena, use of fossil fuel for heating), a high percentage of this planted forest has been without any management planning. In addition, the abandonment of agriculture and sheep-farming has determined the natural recolonization of several areas which are now again covered by woods and forests. The situation is quite diverse in lowland areas, where the percentage of forested area is very low and mainly concentrated along river banks and in parks with prevalent ecological and naturalistic functions. In such areas, several regions are promoting reforestation programmes through the creation of multifunctional green systems, ecological nets, hedges and (semi-) natural boundaries.

A recent planning tool promoted by Regione Lombardia in the north of Italy is aiming to achieve sustainability by stimulating local planners to look for and design new forests in lowlands areas where they have never existed, or at least not in recent times. These forests will be permanent; this is a critical step for local planning strategies, but they will meet some environmental objectives like improving land quality, creating web systems, opening forests and forestry to people, increasing social use of the woodland environment and raising the level of biodiversity (Lassini *et al.*, 2003).

Woodland area

The area of woodlands of 0.5 ha and over is close to 105 000 km^2, equivalent to 34.7 % of the total land area in Italy. Forests are the main woodland type, accounting for 83.7 % of the total woodland area, and are almost all high forests (Table 9.1). Within the various regions of Italy both the distribution and types of woodland are very uneven. Woodland cover is generally higher in central and northern Italy (with the exception of the lower Po Valley, where woodlands have almost disappeared), and ranges from less than 10 % of the total land area for Apulia in the far southeast to 69 % for Liguria in the northwest. The distribution of the different types of woodland also varies with latitude, with an increase in bushes, garrigues (soft-leaved scrubland) and Mediterranean maquis in the south, where this type of woodland reaches up to 25 % of total woodland area, as in Sardinia.

Table 9.1 I Types of woodland. Source: INFC (2007a), modified.

Land use	Area (ha)	Percentage (%)
Forests [a]	**8 759 200**	**83.7**
High forests	8 582 968	98.0
Productive plantations	122 252	1.4
Temporarily unstocked lands, e.g. windblown, felled	53 981	0.6
Other wooded lands [b]	**1 708 333**	**16.3**
Low forests	124 229	7.3
Thin forests	146 415	8.6
Shrublands (mainly Mediterranean maquis)	1 039 594	60.8
Unclassified / inaccessible woodland areas	398 095	23.3
Total	**10 467 533**	**100**

[a] Defined as land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use (FAO, 2000).
[b] Defined as land not classified as forest, spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of 5–10 %, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 %. It does not include land that is predominantly under agricultural or urban land use (FAO, 2000).

As reported by Nocentini (2006), virtually all forests are seminatural, with some areas of plantations, including introduced species, such as poplar, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), radiata pine (*Pinus radiata* D. Don) and eucalyptus (*Eucalyptus* spp.); the area of forests and other woodlands undisturbed by man is small.

Topography and climate

Italy's mainland is generally hilly and mountainous, except for the fertile Po River Valley in the north and the narrow coastal belts further south. At the foot of the Alps, the Po, the only large river in Italy, flows from west to east, draining plains covering about 17 % of Italy's total area and forming the agricultural and industrial heartland. The Apennines, the rugged backbone of peninsular Italy, rise to form the southern border of the Po Plain. Numerous streams and a few rivers flow from the Apennines including the Arno and the Tiber which flow to the west coast. Sicily, separated from the mainland, includes the Madonie Mountains, a continuation of the Apennines, and the Plain of Catania, the largest plain on the island. Sardinia, in the Tyrrhenian Sea, is mainly mountainous.

Most of Italy has a Mediterranean type of climate, which has relatively cool, rainy winters and hot, dry summers. Italy is included between the annual isotherms of 11 °C and 19 °C, but climate varies widely with elevation and region. The coldest period occurs in December and January (mean January temperature spanning from –3 °C to +11.4 °C), the hottest in July and August (July mean temperature spanning from 17.0 °C to 26.5 °C) . In the Po Plain, the average annual temperature is about 13 °C; in Sicily, about 18 °C. The climate of the Po Valley and the Alps is characterized by cold winters, warm summers, and considerable rainfall mostly in spring and autumn, with snow accumulating in the mountains. Mean annual rainfall varies from less than 500 mm on the southeast coast and in Sicily and Sardinia to over 2000 mm in the Alps and on some westerly slopes of the Apennines. Frosts are rare in the sheltered western coastal areas, but severe winters are common in the Apennine and Alpine uplands.

Species composition

The various environmental conditions determined by the large range in latitude and altitude within Italy and the high percentage of semi-natural forests cause a well-differentiated spectrum of woodland types, forest patterns and species composition (117 species were found). Native broadleaves predominate: 67 % of high forests (about 5 942 000 ha) consist of broadleaved woodland, while pure coniferous forests occupy only 13% of the total high forest areas, the remaining 20% being mixed woodlands of conifers and broadleaves.

Oak broadleaved forests comprising *Quercus robur* L., *Q. petraea* Liebl. and *Q. pubescens* Willd. occupy more than 1 084 250 ha, followed by beech (*Fagus sylvatica* L.) forests with 1 035 000 ha, mediterranean oak woodlands with 1 011 000 ha (*Quercus cerris* L., *Q. ilex* L., *Q. trojana* Webb, *Q. frainetto* Ten. (syn. *Q. conferta*, *Q. farnetto*), etc.) and by chestnut (*Castanea sativa* Mill.) woods with 788 400 ha, 77 % of which is devoted to wood production. In the coniferous forests the most represented species is Norway spruce (*Picea abies* (L.) Karst) with 588 000 ha, followed by European larch (*Larix decidua* Miller syn. *L. europaea*) and Swiss stone pine (*Pinus cembra* L., 388 000 ha in total) and various Mediterranean pine species (e.g. *Pinus pinaster* Ait, *P. pinea* L., *P. halepensis* Miller).

Productive plantations are mainly poplar woodlands (66 300 ha) and *Eucalyptus* spp. (about 20 000 ha), and only 15 000 ha are of coniferous plantations. It should be noted that data about productive plantations are underestimated. Table 9.1, which is included in the recent National Forest Inventory (INFC, 2007), is based on the FAO definition of forest, that 'does not include land that is predominantly under agricultural or urban land use, while in Italy most of the new plantations were set up in agricultural areas as a result of EU regulations supporting afforestation of agricultural land; during 1994–2000 about 104 000 ha of new plantations were established to comply with EEC regulation 2080/92 (Colletti, 2001). In addition, part of the afforestation with coniferous species accomplished between the 1960s and 1970s is not included in this category because these plantations, originally created with a productive goal, have moved towards protective or other functions and are now identified as high forest.

As for the mean increment of the country growing stock, data from the latest National Forest Inventory (INFC, 2007b) indicate an annual increment of forests of 36 million m^3, with an average of 4.1 m^3 ha^{-1} yr^{-1}. This value is quite variable among the different climatic regions and woodland types. Average productivity in Norway spruce high forests is about 7.8 m^3 ha^{-1} yr^{-1}, beech forests increase at a rate of 5.4 m^3 ha^{-1} yr^{-1}, while the rate of increase in oak forests ranges from about 2 to 3 m^3 ha^{-1} yr^{-1}.

Ownership and subsidy regime

About 63 % of woodland areas are privately owned, while more than two-thirds of the remaining areas are owned by local municipalities and provinces (INFC, 2007). Private woodlands are highly fragmented, the average size of a property being 7.5 ha (ISTAT, 2001), but various forms of joint forest management exist, often derived from local rules still based on Middle Ages' rights.

Apart from widespread legal constraints for hydrogeological and soil preservation reasons regarding more than 80 % of the entire Italian woodland area, about 2 500 000 ha of forests and about 400 000 ha of other wooded lands is protected and included in national, regional or local parks and reserves in line with European and local regulations (i.e. Natura 2000, people rights, etc. http://ec.europa.eu/environment/nature/natura2000/index_en.htm). A national framework of forest rules exists, but almost all matters regarding tree harvesting are under the umbrella of regional administrations. As a consequence forest work must be authorized at regional level, following different rules and procedures from region to region. The same situation exists for subsidies, which are defined at regional level and often pursue different aims; it is therefore not easy to point up a comprehensive framework of this kind of financial support. The current European Regional Development Fund (ERDF 2007–2013 http://ec.europa.eu/regional_policy/sources/docoffic/official/regulation/newregl0713_en.htm) is however fostering the harmonization of funds in the different regions.

Silvicultural systems

Soil and water conservation are the main goals and constraints of recent forest management: forestry practices are carefully controlled and restricted under specific rules, which aim for sustainable planning and management of forest land. Another current important aim is to foster natural diversity and evolution in forestry habitats; therefore mixed forests are promoted and the spontaneous recolonization of native species (namely broadleaves) in mainly coniferous plantations is strongly encouraged.

Coppices are widespread, especially within privately owned woodland. The most common is simple coppice with rotation standards left to favour substitution of old stumps and seed production. Coppice with standards has been used in some areas of central Italy for pure or mixed oak stands, e.g. *Quercus ilex* L., *Q. robur* L., *Q. cerris* L. and *Q. pubescens* Willd. More and more coppice stands (i.e. in beech woods), especially in public woodland, are being converted to high forest. Conversion usually begins with thinning in coppices that are generally older than their usual rotation cycle. When stems are relatively old, soil has improved and seed production is abundant, the shelterwood system can then be adopted. Criticism of this system still exists, as there is still a well-founded traditional interest toward coppicing which, in certain conditions, represents the only renovation system possible. Socio-economic changes have prolonged the cutting turn.

Although still common in Italy, coppicing is sometimes considered an outdated silvicultural system, though in some cases without a specific technical reason. This is because its products are largely substituted by other manufactured items and it doesn't guarantee, as efficiently as high forests, the multiple functions that public opinion expects (e.g. soil erosion control, landscape amenity and recreation). The high forest management is strictly related to the geographical and ecological context. Clearcutting of high forest has recently been prohibited at general and national level (regulation D. Lgs. 227/2001) and it can be adopted only for specific woods (e.g. coastal stone pine forests) and in limited areas. As reported by Pettenella *et al.* (2005), selection systems and shelterwood systems (mainly group, stripe or edge) are presently the most common silvicultural systems used in alpine high forests (especially in coniferous forests of Norway spruce or in mixed forests). These systems are strongly encouraged because they lead to natural regeneration. This kind of treatment has determined the shifting of many even-aged forests (developed from previous clearcutting or afforestation) to uneven-aged or irregular forests. In beech high forests the most common practice is the uniform system cuts. The opening of gaps or stripes by clearcutting is only allowed in stands composed of light-demanding species (i.e. European larch and Scots pine, *Pinus sylvestris* L.), in order to meet the ecological requirements of these species and to guarantee the stand natural regeneration. Special rules also cover the regeneration of white fir (*Abies alba* Mill.) woods in some regional contexts where historical and cultural reasons require conservation of the landscape.

As a result of the above mentioned reasons, planting of new forests is a limited practice in Italy and very little information is available regarding the average establishment cost per hectare, which is quite variable according to the type of plantation, density, species, location, cultural models, etc. In areas where new plantations have recently been established for biomass production or fuelwood chip, i.e. poplar (*Populus* spp.), and/or for the production of high quality timber – mainly cherry (*Prunus avium* L.) and walnut (*Juglans regia* L. and *J. nigra* L.) – the situation is quite diverse in terms of management planning, and herbicides are sometimes used. In some cases weed control has been solved by increasing the planting density, by sowing herbaceous crops and mulching with woodchips.

Herbicide use and comparisons

The use of herbicides to control vegetation in woodlands has never been common practice in Italy and the recent emphasis on renaturalization of forest systems and environmental side-effects of pesticides has further reduced herbicide use. Exceptions can be found in productive plantations and agroforestry, but here mulching and soil cultivation remain the preferred options. No data are available on herbicide use in Italian forestry, and a limited number of products have been registered in Italy. In practice herbicide use relates only to forest nursery management and is largely used in specialized work, i.e. Christmas tree production and high-quality timber production at nursery stage (Maetzke and Sanesi, 1992). In both cases the use of chemical herbicides was introduced at the end of the 20th century.

Policy drivers and pesticide regulation

Herbicide use in forestry can be limited in a variety of ways by regional regulations which aim to preserve habitats and spontaneous vegetation. Even in poplar plantations some eco-labelling protocols, for example FSC (Forest Stewardship Council http://www.fsc.org/en/), limit herbicide-based weed control.

Weed problems

The highly varied range of environments, types of woodlands and management practices in Italy makes it difficult to generalize about weed problems. In productive plantations, including short rotation forestry, weed flora are dominated by annual fast growing species and competition is mainly for water and partly for light. Competition for water is increasingly important further south, where it becomes the main limiting factor in new plantations. In semi-natural situations, with slower growing trees and reduced management practices, the role of perennial weeds and woody species is more relevant, and bramble (*Rubus fruticosus* L.), tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle), black locust (*Robinia pseudoacacia* L.), box elder (*Sambucus nigra* L.) and other less widely spread woody weeds can strongly affect tree growth and survival.

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Italian forests

Silvicultural systems

Alternative silvicultural approaches in the management of woodlands in Italy are not very widespread and are mainly related to changing the scope of forest plantation from production to bio-ecological conservation and environmental protection. In response to this, recent decades have seen the emergence of ecosystem management and alternative techniques such as selective thinning, patch or partial cutting, and the recycling of older practices such as under-planting in shelterwoods, two-storeyed or mixed stands and continuous cover forestry (CCF). These changes will probably also lead to a change in weed management which considers the overall environment but is not always cost-effective. In this scenario support from the state and/or region(s) is needed.

Mechanical methods

Mechanical weed control, such as cultivation or mowing, is one of the oldest agricultural practices and in places is still used for new plantations, especially those planted after 2080/92 regulations and in special projects (Lassini *et al.*, 2003). Mechanical weed control aims to limit competition by uprooting, separation of the green stem and leaves from the root system, or a total maceration of the weed plant. Mowing by machine is carried out two or three times a year according to the weather, latitude and species growth.

Cultivation

In Italy the cultivation and forestry of valuable broadleaved species are mainly carried out in hilly or mountainous areas, sometimes close to the limits of cultivation. In these situations soil tilling can lead to erosion which can be serious, depending on the types of soils (texture and structure), rainfall regimes, plot dimensions, slopes, etc. However, mechanical practices are sometimes used to achieve the desired level of weed suppression in some ValBroS. This activity either kills the weed completely or causes sufficient injury to render the plants non-competitive (Zeleznik and Zollinger, 2004). Repeating the mechanical treatment will result in a shift to weeds that tolerate the practice. Deep-rooted perennials tolerate cultivation and prostrate weeds tolerate mowing. Weed shifts can be minimized by integrating several weed control practices, including various herbicides, or by rotating practices from one season to another.

Mechanical weed control can be effective for control of annual weeds, especially at seedling stage. However, cultivation may bring weed seeds to the soil surface where they can germinate. Seed dormancy may be broken by exposure to light during tillage or by other changes in the environment around the seed. Therefore, shallow cultivation is encouraged to reduce the number of dormant weed seeds brought to the surface. Repeated tillage may be required throughout the growing season as new weeds emerge. Cultivation actually propagates and spreads a perennial weed problem throughout the tree planting as rhizomes, stolons, tillers, tubers or roots are spread by the cultivation tool. After young trees are established and growing, mechanical cultivation deeper than 5–10 cm can damage tree roots, resulting in stunted growth.

Mulches

For in-row management, especially in the first years after planting, mulching with plastic or organic materials can be advantageous. This is a valid alternative to tilling though it is not very widespread. Problems encountered using plastic materials include: an increased likelihood of anaerobic conditions caused by excessive soil water content; the high costs of purchasing and of the manual labour needed for applying them; the non-biodegradable residues. But it is important to emphasize that biodegradable films are now marketed, although contrasting information exists about their full degradability. In Italy mulching experiments using different plastic films have been carried out in wood production plantations, especially in those which receive subsidies from the European Community (Reg. EC 2080/92). (http://ec.europa.eu/agriculture/envir/report/en/forest_en/report.htm).

Organic mulching with different materials, mainly shredded wood, chipped wood, pine bark and composted materials (Photos 9.1 and 9.2), skilfully applied, is an environmentally friendly way of establishing, protecting and managing young trees at a low cost in a new plantation. These mulching materials also contribute to better long-term growth by improving the organic matter content of the soils and by affecting other soil characteristics. With regard to this, some experimental trials carried out in Italy have shown that organic mulches, especially coarse green compost, increased growth and gas exchange of two widely used tree species, horse chestnut (*Aesculus* x *carnea* Hayne) and European linden (*Tilia* x *europaea* D.C.), and soil temperature under the mulch was significantly lower than in bare soil (Ferrini et al., 2008a). Similar results were obtained with hedge maple (*Acer campestre* L.) and European hornbeam (*Carpinus betulus* L.) (Fini *et al.*, 2008). Soil biological activity was also enhanced by the mulch. No difference in soil oxygen content was found compared to non-mulched plots, indicating that the use of a mulch layer up to 8 cm thick did not diminish gas exchange between soil and atmosphere. Also soil bulk density and soil temperature values were significantly lower under the organic mulch treatments. Conversely, soil moisture increased significantly. Compost mulching also had a fertilizing action, as shown by higher total soil N content and (Ferrini *et al.*, 2008b).

However the use of mulching in Italy is still limited to experimental plots. Results are sometimes not as good as expected, especially when the material is of insufficient quality to support satisfactory plant growth and tree quality. Some mulch materials can affect trees in a negative way; this can be related either to their quality or to their misuse. The materials need to be well characterized for nutrient values, stability and other properties for the support of tree growth and effectiveness against weeds. Recent research therefore suggests that mulching should be designed and used to match specific requirements. For example, composts for mulching should consist of layers of different particle sizes, so that nutrients needed by the young trees are supplied and weeds are not given good germination conditions. Unfortunately, unless the compost or other mulching materials are locally produced, transportation costs make this technique uneconomical.

Biological weed control

Grazing animals such as cattle, sheep and pigs are not used in Italy to control weeds. Biological weed control, based on host-specific natural enemies (i.e. arthropods and diseases), though of potential use in forest plantation, is not used or is limited to research plots.

Herbicides

Only two active ingredients are currently registered in Italy as herbicides for forestry: propyzamide and triclopyr. No commercial product based on propyzamide is available at present, so triclopyr is the only permitted herbicide; it is mainly used against bushes and small trees in coniferous plantations, given its selectivity toward genus *Pinus, Picea* and *Abies*. Other active ingredients registered for more specific uses are: glyphosate, glufosinate and oxifluorfen in forest and poplar nurseries, and oxadiazon and pendimethalin in poplar plantations.

Ground cover

A permanent herbaceous cover can increase soil fertility and reduce the rate of soil erosion, as is evident from research in commercial orchards (Loreti and Pisani, 1986). In Italy cover crops are commonly used in fruit orchards, Christmas tree plantations and other forest plantations to reduce muddy conditions and allow access between tree rows for harvesting and maintenance activities. When planted between tree rows (Photo 9.3), they can reduce the spread of invasive weed species by minimizing their establishment. If weeds do become established, cover crops can control them by shading and competing for water and nutrients at critical times of growth. Cover crops planted between tree rows allow better rainwater penetration into fine-textured soils. More importantly, they can reduce soil erosion and eliminate the drying effects from tillage. However, a weed-free zone should be maintained within the rows or for approximately 1 m around individual trees to minimize competition for water and nutrients. At present natural ground cover is still the most widespread and the cover can be permanent or, more easily, temporary. Some research projects are still in progress in Italy to evaluate the effect of ground cover on some valuable broadleaved species (see below).

Barriers to adopting alternative methods

In Italy the main barrier to adopting alternative methods is their higher cost. The limited use of mulching is mainly related to the work needed to lay it down and to the lack of specific machines which are used in the horticulture sectors (fruit culture and vegetable crop cultivation). Use of cover crops is not very widespread, in spite of the fact that this technique has shown positive results in terms of erosion control (on hilly areas) and enhanced plant growth; the main challenge is to find the balance between the potential benefits and the potential drawbacks (water competition) of this cultivation technique. Table 9.2 shows a comparison of the different methods used to control weed growth.

Tool	Advantages	Disadvantages
Cultivation	• Effective • Non-selective • Equipment readily available	• May damage soil structure • Spreads perennial weeds • May damage trees/roots • Short-term control
Mulching	• Effective • Non-selective • Holds moisture • Long-term control	• Availability of mulch • Cost of mulch and its application • Attractive to rodents • May affect nutrition • Must be free of seeds
Mowing	• Rescue treatment • Quick suppression • Equipment available • Reduces seed spread	• Weeds may still compete • Quick regrowth • Several mowings required • May damage young trees
Herbicides	• Effective • Easy to apply • Can be selective • Timely	• Effects on pest complex • Variations in cost

Table 9.2 | Advantages and disadvantages of weed management strategies (adapted from Carter, 2003).

Ongoing research

Research projects carried out to investigate the influence of weed control systems on survival, height growth and crown architecture of Christmas trees showed that the last two parameters were higher when weed control was utilized. Herbicides were the most effective control system, while no significant differences were found among the different mulching systems (Maetzke and Sanesi, 1992; Calamini *et al.*, 1998).

Grants from the European Union (EU Regulation 2080/92) enabled experimental work on new forest tree plantations to be established on former agricultural lands, mainly on walnut. As highlighted by Paris *et al.* (2005), current cultural models of plantation forestry in Italy do not utilize tree association either with herbaceous cover or with intercropping. The second option is not allowed by the EU Reg. 2080/92, despite the fact that the cultivation of a herbaceous understorey amongst the trees can be a very favourable option with several ecological and economic benefits (Paris *et al.*, 2001). In the case of cash or fodder crops (agroforestry cultural models), their early returns can partially offset the long cultivation cycle of trees. On the other hand, associated herbs can strongly compete with young trees for water and/or soil nutrients and can dramatically reduce their early growth (Paris *et al.*, 1995, 1998). In order to avoid or reduce competitive interactions, specific cultural treatments and species combinations may be required that are appropriate for the site conditions. The tree–crop interface is a key factor in any modern agroforestry cultural model in plantation forestry.

Although herbicides are commonly used to reduce the competition between herbaceous vegetation and newly established trees, mulching around the trees may be a more suitable option. Polyethylene mulching spread out along the tree row was shown to be a highly effective means of decreasing the competitiveness of intercropped alfalfa *(Medicago sativa)* towards young walnut trees in a Mediterranean site in central Italy (Paris *et al.,* 1995, 1998). The competition intensity of herbaceous crops towards trees can also be strongly affected by the species composition of the herbaceous understorey.

A research project reported by Paris *et al.* (2001) has shown the benefits of in-row plastic mulching together with the between-rows ground cover using a low competitive subclover (*Trifolium subterraneum* L.). After seven years the growth of walnut trees was much higher compared to weed control using herbicide.

Recent research conducted by Facciotto *et al.* (2006) on poplar plantations has shown that among different methods to control weeds, the use of chip wood has been efficient even against aggressive species like *Sorghum halepense*. Root rot was not detected and plant growth was not reduced. Ground cover was not efficient as well, probably because seed germination was scarce. The application of mulching material in the urban forestry sector has shown positive results in terms of increased tree growth and leaf gas exchange, especially when composted material from green waste is used (Ferrini *et al.*, 2008a; Fini *et al.*, 2008). The recent increase in short rotation forestry (SRF) for biomass production, mainly on fertile agricultural areas and managed as a crop, has stimulated research on herbicide use and selectivity. Cuttings and young trees are characterized by a late sprouting and initial slow growth and are therefore highly sensitive to competition. The focus is thus mainly on testing of soil-applied herbicides with residual action, in order to protect the plantation at the beginning of the growing season, and on analysis of clone sensitivity to herbicides. Similar research has recently been carried out at nursery level (Bisoffi and Facciotto, 2000; Balsari *et al.*, 2002; Belia *et al.*, 2007).

Future research needs / potential for European collaboration

Examples of future research needs and potential for European collaboration include:

1. Developing sustainable cultivation protocols with no use or low use of herbicides and pesticides.
2. Obtaining high growth rates of the cultivated species subjected to low-impact cultivation techniques.
3. Determining how different soil covers (i.e. mulches) affect the root and soil environment and their interaction with irrigation regimes.
4. Developing weed management systems that minimize the use of herbicides, including the use of non-competing species as cover crops.
5. Developing a common protocol for field experimentation to allow testing of similar products in different climatic zones of Europe and provide demonstration sites for managers.
6. Carrying out trials in different climatic zones in Italy.
7. Disseminating results in scientific papers.

Barriers to carrying out future research

The main barrier is the lack of funding for this kind of research. Though current interest in forestry and agroforestry in Italy relates mostly to the wider general focus on sustainable agriculture for environmental protection, this focus is often in great contrast to the urgent economic needs of rural people. A partial solution to this problem may come through funding from the European Union for sustainable agriculture and afforestation of arable lands.

Ecosystem responses

Current knowledge

Effects of weeds on trees

Weeds and natural or artificial ground cover compete against trees for water, sometimes with considerable negative effects. This is the main obstacle to the application of natural ground cover in areas characterized by drought periods. However the level of competition for water is variably influenced by different factors, for example soil characteristics, the rainfall regime (frequency and distribution) and the water requirements of the different species. This means that the problem of water competition cannot be generally extended to all the environments in Italy, where pedoclimatic conditions are really variable from North to South and East to West, but needs to be evaluated in any specific situation. Effects have been also found on nutrient dynamics, particularly nitrogen; by competing for certain nutrients the ground cover usually reduces soil nitrogen content, but also helps to keep it constant during the growing season and to increase organic matter content in the long term.

Nature and magnitudes of effects

Alternative and new cultural models, such as agroforestry, have been studied for replacing hardwood plantation forestry. These studies are in connection with the Mediterranean tradition of mixed cultural systems, which are now marginal. Research shows that both cultural models have numerous advantages when compared to traditional forestry plantations. Tree growth and timber quality are often improved due to enhanced tree care, better site quality and synergisms among plant/system components. Technical advantages are augmented by ecological ones, such as improved biodiversity, soil erosion control and reduced fire risk. Agroforestry can be more effective than pure cultivation for the restoration of degraded agro-ecosystems and for the preservation of rural landscape.

Impacts of control methods

Impacts of the various control methods are summarized in Table 9.2.

Ongoing research

Research projects are taking place in different parts of Italy; these are mainly related to the use of alternative techniques and their effects on soil characteristics and to test the ecophysiology of woody species, but they are limited to the agroforestry and urban forestry sectors.

Future research needs / potential for European collaboration

Future research needs, which many also have potential for European collaboration, can be summarized as follows:

1. Evaluation of soil qualities and compost additives that give the best growth, health and general quality in shrub and tree species.
2. Knowledge on how mulches (both organic and plastic) can be used to decrease weed problems and affect plant ecophysiology.
3. Knowledge on how to use ground cover for fast establishment and growth of trees to promote plant performance and longevity.

Barriers to carrying out future research

The main obstacle to carrying out future research projects is the lack of funding and of precise planning by the state and regional authorities.

Society and vegetation management

Current knowledge and ongoing/future research

No formal research appears to have been carried out or is ongoing specifically into the social dimensions of vegetation management within woodlands in Italy.

Barriers to carrying out future research

The main barrier is lack of funding coupled with lack of planning.

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10

Lithuania

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Country background

History

In the Middle Ages Lithuania was famed for its woods teeming with birds and animals. Then, due to extensive hunting, some species of wild animals became scarce. Timber and its products, such as ash and potash, were shipped in great quantities to western Europe to meet the high demand. As a result, the edges of forests alongside the country's rivers were felled first. At the same time, forests were intensively colonized. During the years of Russian rule and German occupation (1795–1918), the forested area of Lithuania was reduced by more than 1 million hectares.

Later, in the 1918–1940 period of Lithuanian independence, larger forest tracts were nationalized and forest cover percentage started to increase. Timber was exported, foresters were trained, and campaigns to protect forests from damage and theft were vigorously conducted. World War II caused much damage to forests but due to the assiduous efforts of foresters, they were soon restored. This was achieved by planting new forests (over 0.6 million ha), by reconstructing the low value stands and by carrying out sanitary and regenerating cuttings.

After the declaration of Lithuanian independence in 1918, the Lithuanian government established the Forestry Department, and approved the law 'To stop the destruction of forests'. In 1919 it approved the 'State supervision in private forests order' which prohibited the reduction of the forest area without a tree-cutting licence. In addition, afforestation of non-wooded areas was planned (Verbyla *et al.,* 2003). From 1938 until 2005 forest coverage in Lithuania increased by 10.2 %. In 1994, the Government approved the Forest Law and this was updated in 1996. According to the Forest Law, afforestation of clearcut areas should be accomplished in 3 years. In 2002, the Government approved the programme for increasing forest area with a planned increase in coverage of 3 % in 20 years.

Topography and climate

Lithuania is situated at the western edge of the East European Plain, which is part of the mixed forest belt of middle climate forest zone. The northern border of hornbeam (*Carpinus betulus* L.) crosses Lithuania. The geographical relief of Lithuania consists of plains with low hills with sod-podzolic forest soil prevailing. The average land surface is 99 m (range 35–292 m) above sea level.

The climate of Lithuania is transitional between maritime and continental, and with strong influence from the Baltic Sea it is relatively mild. Mean annual air temperature is +6 °C (January -4.8 °C; July +17 °C) and average precipitation is 650 mm (mean annual range 540–930 mm). The average growing season (mean of growing degree-days above 5 °C) lasts 175 days (range 169–202 days).

Woodland area

Woodlands occupy 2.1 million ha or 32 % of the land area (Table 10.1). Over 22 000 ha (1.1 %) of virgin natural forests remain in Lithuania (Table 10.2). Almost 72 % of the woodland area is occupied by natural and semi-natural forests. Plantation woodland covers 22 % and the remaining 5 % is non-forested, consisting of linear constructions (e.g. roads, rides), special purpose forest land such as nurseries and other forest land like woodyards and recreation areas.

Land use	Area (ha)	Percentage (%)
Forest land area	2 091 000	32.0
Agriculture	3 482 900	53.3
Urban/other	956 100	14.7
Total	**6 530 000**	**100**

Table 10.1 I Land use in Lithuania. Source: Land fund of the Republic of Lithuania and State Forest Survey Service.

Land use categories	Area (ha)	Percentage (%)
Virgin natural forest	22 000 [a]	1.1
Natural and semi-natural forest	1 502 559 [b]	71.8
Plantation woodland	463 139 [b]	22.2
Non-forested area (clearcut areas, open areas, land for afforestation)	66 312 [b]	3.2
Special-purpose forest land (nurseries, seed orchards, landscape plantations)	2 637 [b]	0.1
Linear constructions (rides, firebreak belts, routes, forest roads)	29 797 [b]	1.4
Other forest land (woodyards, feeding places for game, recreation and landscape sites)	4 738 [b]	0.2
Total	**2 091 182 [b]**	**100**

Sources: [a] Conservation and Sustainable management of Forest in Central and Eastern European Countries (European Commission, 1999); [b] State Forest Survey Service (2005).

Table 10.2 I Forest land area by land use categories.

Species composition

Native tree species prevail in Lithuanian forests. Scots pine (*Pinus sylvestris*) stands occupy the greatest area (36.2%) followed by Norway spruce (*Picea abies:* 21.8 %), birch (*Betula* spp.: 20.6 %) and other broadleaf species. Introduced exotic species such as larch (*Larix* spp.), pines (*Pinus* spp.), red oak (*Quercus rubra*) and others are grown in plantations, and cover less than 1 % of the woodland area (Table 10.3). A summary value of average productivity of the growing stock in Lithuania is 6.5 m^3 $ha^{-1}yr^{-1}$.

Land use	Area (ha)	Percentage (%)
Scots pine *Pinus sylvestris*	719 300	36.2
Norway spruce *Picea abies*	432 700	21.8
Other conifers	3 100	0.2
Birch *Betula* spp.	409 900	20.6
Aspen *Populus tremula*	62 900	3.2
Black alder *Alnus glutinosa*	131 800	6.6
Grey alder *Alnus incana*	125 500	6.3
Oak *Quercus* spp.	38 600	1.9
Ash *Fraxinus excelsior*	48 800	2.4
Other broadleaves	15 100	0.8
Total	**1 987 700**	**100**

Table 10.3 I Forest stand area by dominant species. Source: State Forest Survey Service (2005).

Forest ownership

Today, forests of state importance make up around half of the Lithuanian forest area, amounting to 1 041 803 ha. Private forests cover 684 451 ha (32.7 %), and forest reserved for restitution covers 364 929 ha (17.5 %). Varying degrees of statutory protection affect woodland management (Table 10.4).

Table 10.4 | Protected woodland areas in Lithuania. Source: State Forest Survey Service (2005).

Land use	Area (ha)	Percentage (%)
Reserved forests [a]	25 172	1.2
Special-purpose forests [b]	253 119	12.1
Protective forests [c]	336 336	16.1
Exploitable forests [d]	1 476 556	20.6
Forest certification [e]	1 041 800	49.8
Felling licence required [f]	2 066 010	98.8

[a] Economic activity not permitted.
[b] Clearcutting not allowed. Natural forest regeneration or forest planting with seedlings, using seeds from former stands, except recreational forest.
[c] Maximum clearcut area 5 ha; preference for natural regeneration.
[d] Maximum clearcut area 8 ha.
[e] State forest certification finished in 2004.
[f] All felling requires a licence, although there are exceptions for precommercial thinning.

Silvicultural systems

Small scale clearcutting and replanting predominates in exploitable forests. In protected forests, clearfelling of small areas and selective cutting are practised more or less equally; the selection system is practised in special purpose forests.

A summary value of the annual area regenerated in Lithuania is 17 000 ha. A summary value of average establishment cost for Lithuania is €770 ha^{-1}. The establishment cost per hectare has a tendency to increase.

Herbicide use and comparisons

Total annual herbicide use in Lithuanian forest lands has been estimated at 5.82 tonnes of active ingredient, approximately 0.7 % of the total pesticide used in Lithuania, despite woodlands making up 32 % of the land area (Table 10.5). Most of the herbicide is used for soil preparation prior to forest planting.

Table 10.5 | Pesticide usage on different crops in Lithuania (data from 2005).

Crop	Total crop area (ha)	% Land area	Area treated (ha)	% Area of each crop treated	Tonnes of active ingredient used	% Total active ingredient used
Forestry herbicides [a]	2 091 000	32.0	3 886	0.18	5.82	0.6
Forestry insecticides [a]	209 100	32.0	2 315	0.11	0.28	0.0
Forestry fungicide [a]	209 100	32.0	408	0.02	0.68	0.1
Agricultural land [b]	3 355 700	51.6	2 238 300	66.70	1048.50	99.3

[a] According to the Forest Sanitary Protection Service (2005).
[b] According to the State Plant Protection Service (2005).

Policy drivers and pesticide regulation

The Lithuanian Government and forest certification encourage the minimization of pesticide use. State forest certification is now complete; private forests are preparing for certification.

Weed problems

Soil characteristics and type of site (e.g. clearcutting area, farmland) have a large influence on the presence and vigour of weed species. The greatest hazard affecting the survival of young naturally regenerating or planted trees on clearcut areas is created by grasses such as rough small-reed (*Calamagrostis arundinacea*) and wood small-reed (*C. epigeios*), bracken (*Pteridium aquilinum*), stinging nettle (*Urtica dioica*), and woody species, for example raspberry (*Rubus idaeus*). Couch grasses (*Agropyron* spp.), bent grasses (*Agrostis* spp.) and other species prevail on former agricultural lands. Soil preparation reduces the prevalence of herbaceous species.

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Lithuanian woodlands

These methods are outlined in Table 10.6.

Silvicultural systems

The order of General Forest Enterprise (2004) requires that selection and shelterwood forest management systems in state forests should be increased by up to 20%.

Mechanical methods

Tending in young stands is mostly carried out manually by cutting grasses with a scythe or hoe (Photo 10.1a and b, page 107). There is no machine cutting.

Site and soil preparation

Herbicides are mostly used before soil scarification to kill grasses and herbaceous and woody weeds. This method is more effective on forest land, less so on agricultural land. Mechanical soil preparation helps to reduce the development of grasses on planting sites.

Mulches and biological weed control

Mulches and biological weed control are not used in Lithuania.

Herbicides

Herbicides are seldom used for the tending of young stands. Glyphosate and fluazifop-p-butyl are permitted in forests and nurseries respectively.

Table 10.6 I Summary of weed types, commonest control methods and impacts in Lithuanian woodlands.

Weed type	Treatment alternatives	Cost (€ ha^{-1}) [a]	Effectiveness	Potential environmental impact
Grasses and herbaceous weeds	Herbicides	40–60	Very effective	Poisoning, soil and water pollution, impacts on non-target flora and fauna
	Cutting by hand, hoeing	50–100	Effectiveness varies with weed and site type	Pollution, disruption to ground-nesting birds
	Cultivation	70–250	Effectiveness varies with weed and site type	Soil erosion, water sedimentation, pollution
Woody weeds	Cutting	50–120	Weakens rather than kills	Pollution, disruption to ground-nesting birds
	Herbicide	40–60	Very effective	Poisoning, soil and water pollution, impacts on non-target flora and fauna

[a] Cost of weed control depends on site type and application method.

Barriers to adopting alternative methods

Although mechanical weed control methods are available, compared with chemical methods they are more costly. The search for alternative weed control methods in Lithuania has not been carried out. The certification of private forests may influence the reduction of herbicide use and the creation of new, economically beneficial, alternative weed control methods.

Ongoing research

Current research includes work on site preparation as a method for reducing herbaceous weeds on planting sites, and for afforestation of former agricultural lands. The development of technology for the stand establishment of oak by direct seeding is ongoing. Afforestation of former agricultural lands is carried out by planting larger, more robust seedlings, which are more resiliant to the negative influence of herbaceous weeds.

Future research needs/potential for European collaboration

Future research in Lithuania requires international collaboration; the use of alternative herbicides, the influence of different soil scarification methods on the development of grass vegetation and investigation on the effects of weeds on trees are all important.

Barriers to carrying out future research

Future research could be hampered by lack of funding.

Ecosystem responses

Current knowledge

Nature and magnitude of effects of weeds on trees

In Lithuania, only research on the general impact of grasses on tree seedlings has been carried out and this was in relation to site preparation.

Ongoing research

Ongoing research is looking at the influence of different soil scarification methods on the development of grass vegetation on planting sites on former agricultural fields.

Future research needs/potential for European collaboration

Requirements for future research in Lithuania, that may be amenable to European collaboration, include: improved understanding of the competitive relationships between different species of trees and weeds; the development of models to predict the response of weeds and tree seedlings to different silvicultural treatments on different sites to aid decision-making and forest management plans.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge, ongoing research and future research needs

The society and vegetation management aspect is not being researched in Lithuania. Research is needed on the evaluation of risk for chemical forest vegetation management practices and possible alternatives.

Barriers to carrying out future research

Future research could be hampered by lack of funding.

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11

Norway

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Country background

History

During the 16th century, mining and sawmill industries were established in Norway. The mining required vast quantities of charcoal, and the development of a large sawmill industry followed by the pulp industries in the last part of the 19th century also required large quantities of timber. This exploitation was carried out without any systematic focus on regeneration, and resulted in sparse stand densities. With the establishment of The National Forest Inventory in 1919 a total overview of forest resources was established. One outcome from this was the revised Forest Act in 1932, which introduced the Forest Trust Fund in order to ensure sufficient regeneration investment.

After World War II governments encouraged forest owners to maximize the productivity of existing forests, through even-aged management, fertilization, site cultivation, improved planting stock and the use of pesticides. Afforestation in the western and northern parts of Norway was a contribution towards achieving this goal. Glyphosate has been the dominating herbicide since its introduction to the Norwegian forest market in 1976. Much effort was made to show how survival and growth of planted Norway spruce was increased by pre-planting application of herbicides or release applications following planting (Lund-Høie, 1984; 1988; Lund-Høie and Grønvold, 1987).

However, since the 1980s there has been a shift in emphasis away from building timber resources towards providing multiple use woodlands (NoU, 1989). In 1998 a consensus was reached between representatives of the government, the forestry sector and several NGOs including the major environmental organizations, through The Living Forest Project (1998). This agreement resulted in a set of national standards for forestry which form the basis for the present certification scheme, approved by PEFC (Programme for the Endorsement of Forest Certification schemes). Certification is however not applied at the individual property level, as it is the Forest Owners' Associations which are certified on behalf of their members. Currently the focus on wood production is increasing due to greater emphasis on forests as a source for bioenergy and CO_2 sequestration (Vennesland *et al.*, 2006).

Topography and climate

The steep terrain in Norway presents challenges for foresters, and part of the forested area is too steep for normal logging techniques. About half of the forested area (productive forest) has a gradient of more than 20 %, and about a quarter of the area has a gradient greater than 33 % (Larsson and Hylen, 2007). The western part of the country and the valleys towards the mountains are especially steep.

The coldest mean temperature in January is in Pasvik close to the Russian border (-14.5 °C). Mean temperature in July varies from 10–11 °C up to 15–16 °C. Annual precipitation typically varies from about 500–700 mm in the eastern part of the country to 1500–2000 mm in the western part of Norway. Mean number of growing degree-days (above 5 °C) varies from about 1000–1100 in the lowland up to 1400 in the south.

Forested area

Forests occupy 12.4 million ha or 38.2 % of the land area of Norway (Table 11.1); 7.4 million ha (23 % of the land area) are productive forests with a potential annual increment of more than 1.0 m^3 ha^{-1} (Table 11.2). Mean annual increment is 4 m^3 ha^{-1} yr^{-1}.

In the western and northern parts of Norway, plantations of Norway spruce (*Picea abies*) and non-native conifer species have been established on previously non-forested land as well as areas previously occupied by less productive tree species.

These afforestation areas represent 2.9 % (211 000 ha) of the productive forest area for the country as a whole (Table 11.2), but regionally they account for over 20 % of the productive forest area.

The remaining 97 % of the productive forests comprise areas with natural forest, regenerated naturally or by planting. The annual regenerated area is about 45 000 ha (Nygaard and Fløistad, 2007). More than 50 % of the area where cutting has occurred has been left for natural regeneration, but not always with the preparation needed to ensure sufficient regrowth of the target species. The average cost of planting amounted to approximately €850 ha^{-1} in 2007 (Statistics Norway, 2008). The area regenerated by planting has decreased substantially during the past 15 years, from around 29 000 ha in 1991 to 13 000 ha in 2007.

Land use	Area (ha)	Percentage (%)
Forests	12 369 000	38.2
Agriculture	1 036 000	3.2
Urban	453 320	1.4
Lakes, marshy land, glaciers	4 144 640	12.8
Mountain	14 377 000	44.4
Total	**32 380 000**	**100**

Table 11.1 I Land use in Norway. Source: Statistics Norway (2008).

Forest type	Area (ha)	Percentage (%)
Productive forest land [a, b]	7 209 000	58.3
Unproductive forest land	4 949 000	40
Afforested areas [c]	211 000	1.7
Total	**12 369 000**	**100**

[a] Site class corresponding to a potential production of more than 1.0 $m^3\ ha^{-1}\ yr^{-1}$.
[b] Source: Larsson and Hylen (2007); the county of Finnmark is not included.
[c] Source: The National Forest Inventory (2006), Rune Eriksen (personal communication).

Table 11.2 I Forest area in Norway.

Species composition

Of the productive forest land 39 % is spruce dominated, 32 % is Scots pine *(Pinus sylvestris)* and 29 % is dominated by various deciduous species. Birches (*Betula pubescens* and *B. pendula*) dominate the group of decidous tree species with 67 % of the volume of the growing stock. On 75 % of the afforestated areas in the western and northern parts of the country, Norway spruce is the main species but planted outside its natural distribution range. Stands of Sitka spruce *(Picea sitchenis)* and the hybrid *Picea* x *lutzii* account for the major part of the remaining 25 % of the afforested area (approximately 50 000 ha).

Ownership and subsidy regime

About 88 % of the forest area is in private ownership, divided among about 116 000 properties. Subsidies for herbicide treatment were terminated from 1991. With respect to other regeneration and tending activities, there are considerable local variations in the subsidy regime as the allocation of state funding to different types of silvicultural activities is decided at municipality level. However, with the exception of certain measures such as herbicide treatment and drainage, the costs of silvicultural activities necessary for the establishment and tending of young stands is eligible for significant tax exemption.

Silvicultural systems

Clearfelling (62 % of the annually harvested area) and the seed tree method (18 %) are the dominating silvicultural systems (Tomter, 2005), but alternative methods including different forms of partial cutting and continuous cover forestry are gaining in importance. Of the total productive forest land in development class 2 (young stands in pre-commercial stage), 52 % and 48 % are naturally regenerated and planted stands, respectively (Tomter, 1999). Natural regeneration is the main method for stands dominated by Scots pine (*Pinus sylvestris*, Photo 11.1) and deciduous species while planting is still used for regeneration on 80 % of the spruce areas (Tomter, 1999).

Herbicide use and comparisons

The standards that resulted from The Living Forest Project (1998) state that use of herbicides in forestry generally should be avoided, and only applied if clearly more effective than mechanical methods. Spraying is not permitted on vegetation that exceeds an average height of 2 m. Total annual use of herbicides in Norwegian forestry was estimated to be 630 kg of active ingredient in 2005 (Statistics Norway, 2006), a decrease of 75 % since 1998 and of 93 % since 1990. Herbicide use in forests accounts for approximately 0.1 % of the total pesticide used (Table 11.4), despite productive forests making up about 23 % of the land area of the country. There are no statistics for the use of herbicides in different crops in Norway, but an overview was made for selected agricultural crops in 2005 (The Norwegian Food Safety Authority, 2006). Therefore it is not possible to identify pesticide use in nurseries or Christmas tree production. The total sales of pesticides are however calculated annually (Table 11.4).

Table 11.4 | Pesticide usage in Norway.

Crop	Total crop area ('000 ha)	% Land area	Area treated (ha)	% Area of each crop treated	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides [a]	7 420 000	23	600	0.008	0.630 [b]	0.1
Forestry insecticides/ rodenticides				–	0.02 [c]	
Total forestry pesticides	**7 420 000**	**23**	**600**	**0.008** [d]	**0.650**	**0.1**
Potatoes [e]	13 662	0.04	13 254	97	N/A	N/A
Apples [e]	1 474	0.005	1 256	85	N/A	N/A
Cereal crops [e]	314 538	0.97	295 473	94	N/A	N/A
Grassland [e]	631 434	1.95	36 822	6	N/A	N/A
Other agriculture land [a]	74 892	0.23	N/A	N/A	N/A	N/A
Urban areas [a]	453 320	1.4	N/A	N/A	N/A	N/A
Total sales of pesticides [f]					**523.5**	

[a] Source: Statistics Norway (2008).
[b] Stump treatment, Christmas tree production and use in nurseries not included.
[c] Source: The Norwegian Forest Society (2007), Tore Molteberg (personal communication). Only prevention use against pine weevils in nurseries just before outplanting in the forest.
[d] Prevention use of insecticides against pine weevils in nurseries not included.
[e] Source: The Norwegian Food Safety Authority (2006).
[f] This includes also use of pesticides (mainly herbicides) in urban areas like roadside, railway embankments and other green areas.
N/A: data not available.

Policy drivers and pesticide regulation

The Norwegian Food Safety Authority is responsible for the regulation of all pesticide use in Norway, including making decisions on which active substances should be approved for use on different areas. The overall aim for the Norwegian government is to ensure sustainable production in both agriculture and forestry. Close to 100 % of timber sold today is from properties using the national forest standard (The Living Forest Project, 1998). This standard states that the use of herbicides is still permitted, but only when it is clear that it will be more effective than alternative methods.

Weed problems

Major problem weed types impacting on the survival and growth of young naturally regenerating or planted trees include the grasses wavy hairgrass (*Deschampsia flexuosa*, Photo 11.2, page 107) and wood small-reed (*Calamagrostis* spp.), the herbaceous species rosebay willowherb (*Epilobium angustifolium*) and meadowsweet (*Filipendula ulmaria*), bracken (*Pteridum aquilinum*), woody species such as birch (*Betula* spp.), raspberry (*Rubus idaeus*), heather (*Calluna vulgaris*) and bilberries (*Vaccinium* spp.).

In the western part of Norway sycamore (*Acer pseudoplatanus*) is becoming more aggressive as a forest weed; elsewhere there are few invasive alien species in forested areas. On clearfelled spruce sites, mechanical cutting of competing woody species is usually necessary. Such tending is performed on about 30 000 ha annually at an average cost of €350 ha^{-1} (Statistics Norway, 2008). On sites with abundant vegetation the cost of mechanical cleaning may be substantially higher.

Treatments and alternatives

Current knowledge

Methods / strategies adopted for managing weeds in Norwegian woodlands

These methods are outlined in Table 11.5.

Site preparation

Mechanical site preparation varies between years and is typically used on about 5000–8000 ha per year (Statistics Norway, 2008), usually on medium to low-productive sites dominated by ericaceous shrubs (mostly *Calluna vulgaris* or *Vaccinium* spp.), with the aim of improving natural regeneration. This is also an efficient way of controlling competing vegetation before planting on medium fertility sites dominated by grass species such as *Deschampsia flexuosa*. The proportion of planted areas treated with mechanized site preparation is however quite low in Norway compared with neighbouring countries Sweden and Finland. Although difficult terrain conditions and the relatively small average size of forest properties in Norway (approximately 50 ha) can explain some of this difference, the potential for such treatment is believed to be much higher than the present level.

Mechanical methods

Motor-manual cutting with a brushsaw is the main method for vegetation control, but the costs of manual labour make it expensive. On fertile sites with a dense cover of deciduous tree species, resprouting from stumps and/or root suckers often leads to repeated overtopping of the crop trees unless herbicide (glyphosate) is applied to the cut stumps. This may result in the need for costly repetition of the treatment, until the crop trees eventually reach the minimum height where they will be able to compete successfully.

Silvicultural systems

Use of silvicultural systems which avoid clearfelling often aim at natural regeneration, and may reduce the need for vegetation management to some extent. One example is the use of selection cutting or high shelterwood systems which reduce the cover of grass competitors such as *Deschampsia flexuosa*. Important limitations to a wider application of this approach are the relatively high harvesting costs and the risk of windthrow which is especially pronounced for spruce stands.

Mulches

Inorganic plastic sheet mulches or organic mulches are not used for weed control in forestry in Norway. Bark and other organic mulches are used extensively in landscape and roadside plantings, and on a small scale in Christmas tree plantations.

Biological weed control

While grazing animals such as cattle and sheep are sometimes used locally to control weeds, to date, host-specific natural enemies have not been exploited for the biological control of weeds in Norway. However, the Norwegian Institute for Agricultural and Environmental Research has experience in biological control of weeds and has been a partner in the EU-project: Enhancement and Exploitation of Soil Biocontrol Agents for Bio-Constraint Management in Crops (2004–2006) (Wang and Netland, 2007).

Seedling quality

A prerequisite for superior field performance is high quality seedlings. When labour costs are too high for the required level of clearing and cutting of competing vegetation, use of sturdy seedlings is particularly important on the most fertile sites. The 2/0 container-grown seedlings in multipot containers with root volume of 75 cm^3 are the sturdiest seedlings in present-day Norwegian forest nurseries.

Herbicides

Herbicide use has declined substantially over the past two decades and at present only about 7 % of planted areas are treated. The only herbicide approved for use in forestry in Norway is glyphosate. For Christmas tree production additional herbicides are approved off-label (Photo 11.3).

Table 11.5 | Summary of weed types, commonest control methods adopted and impacts in Norwegian forestry.

Weed Type	Treatment alternatives	Cost (€ ha^{-1}) [a]	Effectiveness	Potential environmental Impacts
Grasses	Herbicides	250	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna, some aesthetic impact.
	Mechanical site preparation	250	Effectiveness varies with weed and site type. Additional cutting of woody species may be needed.	Soil erosion, nutrient leaching, disruption to ground-nesting birds, some aesthetic impact.
Herbaceous weeds	Herbicides	250	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna, some aesthetic impact.
	Cutting	350	Repeated interventions may be necessary.	Disruption to ground-nesting birds, some aesthetic impact.
Woody weeds	Herbicides	250	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna, some aesthetic impact.
	Cutting	350	Weakens rather than kills; repeated interventions may be necessary due to resprouting.	Disruption to ground-nesting birds.

[a] Cost is estimated for one treatment; repeated interventions (2–3 times) may be necessary when manual cutting is carried out.

Barriers to adopting alternative methods

Economic pressures had a great effect when the government support for herbicide use in forestry was banned from 1991. The use of herbicides to promote forest regeneration decreased from about 10 000 ha to about 3000 ha sprayed annually in 1998. Following the introduction of the national set of criteria and indicators for sustainable forest management (The Living Forest Project 1998), the decrease continued to the present-day level of 600 ha sprayed annually (Statistics Norway, 2008). Alternative approaches often incur high costs and the main challenge is therefore to provide fresh knowledge on how to establish new forest after clearcutting on the most fertile sites, without herbicides, and in a cost-efficient way.

For Christmas tree production and in nurseries, herbicides are still the most cost-efficient method for weed control. However, new regulations in the EU and Norway have resulted in a decrease in the number of approved herbicides available.

Ongoing research

Current research includes work on seedling quality and how growing regimes in the nursery may establish more sturdy seedlings. In addition, long-term effects of different soil scarification methods are being analysed. Concepts for continuous cover forestry are also being studied. Alternative herbicides for Christmas tree production are being tested on a small scale. A new research project started in 2008 aims to analyse the consequences of reduced investment in silviculture on middle fertile forest sites.

Future research needs / potential for European collaboration

The use of sufficiently high seedling quality for planting on fertile sites, coupled with limited vegetation control, is one method that should be studied further. Development of cost-efficient methods for control of woody competitors, such as the use of deciduous trees as a nurse crop during the early phase in coniferous regenerations, should also be considered. This approach could possibly be used to reduce the problem with resprouting, while maintaining high yields and a potential for early harvesting of the nurse crop biomass for bioenergy purposes, for example. With alternative harvesting systems, there is a need to determine the optimal residual tree stocking to obtain sufficient vegetation control on various site types. In particular there is limited experience with alternative silvicultural systems on richer sites.

For Christmas tree production and nurseries there is still a need to identify cost-efficient methods for weed control. In the production of Christmas trees, weed control is one of the most expensive operations and there is a need to develop cheap and efficient control methods.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Ecosystem responses

Current knowledge

Effects of weeds on trees

Competition from weeds for soil moisture, nutrients and light leads to reduced tree growth as well as increased mortality. This competition will usually be most pronounced on high site indices with a high coverage of grasses and herbs. However, competition may also be substantial on low site index sites with extensive cover of ericaceous species like heather (*Calluna vulgaris*) or bilberry (*Vaccinium myrtillus*), which are very common species in Norwegian forests (Nilsson *et al.* 1996; Norberg *et al.*, 2001). Some species may also restrict forest regeneration through allelopathic effects, for instance the dwarf shrub crowberry (*Empetrum hermaphroditum*; Nilsson *et al.*,1993).

Nature and magnitudes of effects

Effects vary according to site (soil and stand conditions), tree species and weed species. The exact nature and magnitude of effects are often not well known.

Impact of control methods

A Norwegian research programme initiated in 1983 studied the ecological consequences of glyphosate application in relation to effects on vegetation and wildlife, as well as soil chemistry and water chemistry. The results were disseminated through a series of papers published in the *Scandinavian Journal of Forest Research*.

Effects on vegetation and wildlife

Lund-Høie and Grønvold (1987) assessed post-treatment vegetation succession in plots treated with either mechanical cutting or late-season glyphosate application. They found that plant species diversity was little affected by herbicide treatment, due to relative rapid recovery. Ferns (*Pteridium aquilinum* and *Athyrium filix-femina*) were however sensitive, showing slow regrowth.

The production of winter browse (young broadleaves) for moose (*Alces alces*) was more negatively affected by glyphosate treatment than by mechanical control, with a reduction to 1% and 60 % of pre-treatment levels, respectively, after two growth seasons (Hjeljord and Grønvold, 1988). Utilization of the herbicide treated area by moose and mountain hare (*Lepus timidus*) decreased after glyphosate application.

Quality of wild forest berries after spraying with glyphosate was investigated by Ogner (1985). During the first 1–3 days after application there were no changes in the vegetation or the taste, flavour or nutrient content of bilberries (*Vaccinium myrtillus*) and raspberries (*Rubus idaeus*). The berries may be harvested without knowing that they are sprayed. Five to six days after application the berries may have a tang or look too unappetizing to be harvested.

Ongoing research

At present, there is no ongoing research directly linked to weed competition among typical forest weed species or on the ecological effects of different treatments. Research within the Norwegian Institute for Agricultural and Environmental Research is taking place on the relative competitiveness of different agricultural weed species, critical periods of weed competition and the biology of weed species.

Future research needs/potential for European collaboration

Examples of potential research topics that may be suitable for collaboration include:

- developing an improved understanding of competitive relationships between different species of trees and weeds;
- the influence of various nurse tree densities on growth of the target species as well as the resprouting potential from cut stumps;
- investigating whether a reduced density of the target species can be compensated for by an appropriate admixture of naturally regenerated woody species to improve timber quality.

Developing models to predict the response of weeds and tree seedlings to different silvicultural treatments would also be of great value.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge

Little formal research appears to have been carried out specifically into the social dimensions of vegetation management within woodlands in Norway. However, research on people's attitudes and preferences in the 1970s stated that the use of herbicides was not well accepted among people who used forests for recreation (Haakenstad, 1972; Lind *et al.*, 1974).

Ongoing research

Recent social research projects concerning forests are focusing on issues such as tourism, urbanism, health, governance and public involvement. Some projects are also focusing on more traditional social and cultural values in forests.

Future research needs

The significance of vegetation, linked to both accessibility of woodlands and quality, for people's health and quality of life will be important. There is also a need for research into attitudes and perceptions of present-day use of forests, including effects of recreational facilities, new silvicultural methods and tourism and recreation. Finally, there is a need for research that could lead to a common planning tool for intensively used vegetation areas in Norway.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

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Country background

History

Early forest administration was established over 126 years ago. Afforestation was instigated at the end of the 19th century by patriotically motivated members of Bulgarian society. In 1885 the establishment of forest plantations started near Knyajevo, Kyustendil, Dupnitsa, Radomir and on some southern slopes of the Balkan Mountains. Particularly significant at the time, and still impressive today, is the famous 'Ayazmoto' (now a park) near Stara Zagora, created under the management of Bishop Metodii Kusev.

During 1904–1909 more than 6 tonnes of seeds from Scots pine, Norway spruce, Austrian pine, Douglas fir and black locust were imported along with Scots pine saplings from Germany for planting new forests in the Kazanlak, Karlovo, Kyustendil, Sliven and Sofia regions. Formally organized afforestation in Bulgaria has a 90-year history, having been designated as a priority for forestry, and organized and carried out under the management of the Forest Service. During this period thousands of hectares of forest plantations have been created. For example, up until 1931, 44 690 ha were afforested and until 1951, 170 000 ha of new forests were established, mainly on bare and eroded forest lands. The average annual planting rates between 1952 and 1996 are shown in Table 12.1. Particularly impressive is the large-scale afforestation which took place during 1952–1980, when more than 1 300 000 ha were planted with the help of mass participation from the Bulgarian population. After 1960 afforestation activity was directed mainly towards the reconstruction of low-production stands, which at that time formed 45.2 % of the total forest area, as well as to restoration of natural non-regenerating stands which made up 20 % of the forest area. The creation of two storey stands and industrial plantations began after 1970, with respective shares reaching 2.5 % and 11.2 % today.

The aim of afforestation in recent years has been the establishment of sustainable stands, well adapted to contemporary environmental conditions, combining ecological and socio-economical functions, based on the preserved high biodiversity of Bulgarian forests.

Until 1990, forest composition was dominated by conifer species (Table 12.2) mainly Scots pine *(Pinus sylvestris)*, Austrian or black pine *(Pinus nigra)* and Norway spruce *(Picea abies)*.

Period (years)	Average annual afforested area (ha)
1952–1960	49 310
1961–1970	56 480
1971–1980	49 480
1981–1990	33 790
1991–1996	12 500

Table 12.1 | Average annual rates for creation of new forests. Source: www.ltu.bg/BG_Gora/Semeproizvodstvo/seme1.html#history

Period (years)	Conifer (%)	Broadleaved (%)
1952 –1960	49 310	27.4
1961–1970	56 480	22.0
1971–1980	49 480	34.4
1981–1990	33 790	40.9
1991–1996	12 500	50.4

Table 12.2 | Relative proportion of conifer and broadleaved species used for afforestation. Source: www.ltu.bg/BG_Gora/Semeproizvodstvo/seme1.html#history

Recent forest management strategic goals are:

- Improvement of forest condition and timber resources.
- Harmonization with general criteria and indicators for sustainable forest management by the implementation of environmentally friendly silvicultural systems.
- Restoration of deforested areas and increase in the sustainability, productivity and carbon sequestration capacity of woodlands.

Among the main priorities is the promotion and conservation of biological diversity.

Topography and climate

The Republic of Bulgaria covers an area of 110 993 km^2, situated in the northeastern part of the Balkan Peninsula between latitudes 41°14 and 44°13 north and longitudes 22°21′ and 28°36′ east. The average altitude of the country is 470 metres above sea level. The Stara Planina mountain range (750 km long and part of the Alpine-Hamalayan mountain range) acts as a natural dividing line from the west to the east.

The Bulgarian landscape shows striking topographic variety with open expanses of lowland alternating with broken mountain country, cut by deep river gorges and harbouring upland basins. The country is split into the traditional regions of North Bulgaria, including the Danubian Plain and the Balkan Mountains, South Bulgaria, including the Rila-Rhodope Massif, and a transitional area between.

Bulgaria has a temperate climate; it can be conditionally divided into two climatic zones. The Stara Planina Mountains are considered to be the watershed between them. Winter temperatures vary between 0° and –7 °C (colder in the north and milder in the south). The average summer temperature is 24°C (range 17–31 °C). Summer is hot and humid in northern Bulgaria, especially along the Danube River while in the south temperatures are usually moderate: about 28–30 °C. Average annual precipitation is 630 mm. The average growing season (mean of growing degree-days above 5°C) is xxx days (range xxx–xxx days). Au

Woodland area

Forests occupy 4 million ha, or around 37.1% of the total land area of Bulgaria (Tables 12.3 and 12.4), among them the woodlands cover 3 704 015 ha. The annual growth is 14.1 million m3, annual harvesting is 7 million m^3 and the total timber volume is 591 million m^3. About 15 000 employers (employees?) work in the forest sector, the greater share being in the forest industry, including 7538 in the State Forestry Sector. Despite Bulgaria's small geographical area, its flora is biologically very diverse with many rare and endemic species. This is due to the extremely varied relief and the geographical position of the country, situated as it is between three climatic districts (Continental Mediterranean, Temperate Continental and Transitional Climatic). To protect this diversity, 3 National Parks, 10 Nature Parks, 55 reserves and 35 maintained reserves have been established. Bulgarian forests are part of the European and world forest resources and their protection is of public importance and priority in the Ministry of Agriculture and Forests policy.

Land use	Area (%)	Percentage (%)
Forests	4 108 494	37.1
Agriculture	6 367 970	57.3
Urban / other	622 236	5.6
Total	**11 098 700**	**100**

[a] The area suitable for use is about 5 800 000 ha.

Table 12.3 I Land use in the Republic of Bulgaria. Source: National Statistic Institute, National Forestry Board (2006).

Most of the forests in Bulgaria are natural (75.6 %). In 2005 the afforested area was 7462 ha, at a cost of approximately €9 million.

Forest type	Area (%)	Percentage (%)
Natural forest	2 777 388	75.0
Secondary and plantation woodland	903 550	24.4
Pinus mugo formations	23 077	0.6
Total	**3 704 015**	**100**

Table 12.4 I Natural and plantation woodland in the Republic of Bulgaria. Source: National Forestry Board (2005).

Species composition

Coniferous tree species make up 31.6 % of the forest structure. Among them the most economically important are Scots pine (*Pinus silvestris:* 17.3 %), black pine (*Pinus nigra:* 8.5 %) and silver fir (*Abies alba:* 0.9 %). Broadleaved stands dominate at 68.4 % of the total. The larger part of the woodland comprises the following deciduous tree species oak (*Quercus* sp.: 32.6 %), beech (*Fagus silvatica:* 14.5 %), black locust (*Robinia pseudoacacia:* 3.3 %), lime (*Tilia* sp.: 1.4%), poplar plantations (*Populus* sp.: 0.6 %) and others (16 %).

Ownership and subsidy regime

Around 76.0 % of woodlands are state owned, 11.6 % are publicly owned and private forests make up 10.2 % (Table 12.5). The overall protected area (National Parks and reserves), where degrees of statutory protection exist, is low at 3.9 %. Owners are obliged to manage their forest according to forest legislation. The Government provides full (100 %) grants for afforestation and new plantations in the state owned territories and financial support with plant material for other public and private forests owners.

Table 12.5 I Composition of forests according to ownership and protected woodland areas in the Republic of Bulgaria. Source: National Forestry Board (2005).

Type of ownership	Area (ha)		Percentage (%) of total woodland area	
	Total	Woodland		
State	3 165 385	2 821 390	76.8	76.1
Include protected forest in National Parks and reserves managed by MEW [a]	(159 435)	(128 927)	(3.9)	(3.5)
Public	464 929	427 773	11.4	11.6
Private forests	393 680	374 441	9.7	10.2
Private forest owned by companies	9 508	8 865	0.2	0.2
Religious	22 666	19 244	0.6	0.5
Forests on agriculture land	53 856	52 302	1.3	1.4
Total	**4 108 494**	**3 704 015**	**100**	**100**

[a] MEW: Ministry of Environment and Water.

Silvicultural systems

Forestry practice in Bulgaria focuses on four major silvicultural systems.

Forest regeneration The natural regeneration and protection of primary forests stands is a priority. The main regeneration fellings are shelterwood systems as the proportion of long-term forests is increased. Clear cuts are limited. The silvicultural systems in pure and mixed spruce, beech, Scots pine and fir forests are directed towards the formation of heterogeneous forests.

Thinnings Thinnings are implemented by a selective approach and special attention is given to those thinnings without timber yield. Thinnings comprise 45–50 % of the total timber harvested volume. In 2007 thinning was carried out on 58 683 ha, which is 88 % of the planned annual thinnings, distributed as follows: 49% in conifer stands and plantations, 30 % in highstem broadleaf forests and 21 % in coppice stands.

Reconstruction of forests Reconstruction aims to overcome the existing incompatibility between the biological requirements of tree species and site conditions. It is implemented by short-term change of tree species by clear-cuts and afforestation.

Conversion of coppice forests into high-stem forests Regeneration fellings with preliminary natural regeneration are carried out, with care taken to protect of the natural stand composition. Selective thinnings are employed. A specific approach is used in forestry planning, determination of rotation periods and production goals.

Herbicide use and comparisons

One of the main activities for effective functioning of the forestry sector is well-organized nursery production which is a prerequisite for the creation of high quality, sustainable forest plantations. Cultivation of seedlings and saplings, including elimination of grassy vegetation, is an important procedure in nursery production. Data from preliminary analysis of the possibilities for solving weed problems via vegetation-protective preparations (chemically based protective preparations, permitted for use in forest nurseries by NSPP) showed that there is only one selective herbicide that could be used for treatment of conifer seedlings. The removal of undesirable vegetation in seedling and sapling nurseries today is done manually, which is time consuming and often ineffective, especially in wet years or in large nurseries. This method is widely used due to the low manual labour prices in our country, but as Bulgaria joins the European labour market salaries will probably rise. On the other hand, decreasing the harmful influence of weeds on saplings can not always be solved with chemical treatment, especially if nursery areas include watershed territory; this necessitates the use of other biologically based vegetation-protective preparations or techniques and/or suitable mechanization.

Herbicide usage in Bulgarian forest protection practice is relatively limited compared to agriculture (Table 12.6). During 2007 the total area treated with herbicide was 6491 ha, with different treatment methods: aviation 2781 ha, ground chemical 1367 ha, mechanical 2343 ha.

Table 12.6 | Pesticide usage on different crops in Bulgaria.

Crop	Total area crop (ha)	% Land area	Area treated (ha)	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides	3 674 320	33.1	94.5	0.601	0.01
Forestry insecticides/ rodenticides	3 674 320	33.1	9 774	3.719	0.08
Forestry fungicides	3 674 320	33.1	271	0.627	0.01
Total forestry pesticides	3 674 320	33.1	10 223	**4.947**	**0.1**
Agricultural herbicides	5 800 000[a]	52.3	N/A	2 698	54.74
Agricultural insecticides	5 800 000	52.3	N/A	528	10.71
Agricultural fungicides	5 800 000	52.3	N/A	1 698	34.45
Total agriculture pesticides				**4 924**	**99.9**
Total				**4 928.947**	**100**

[a] The area of agriculture lands suitable for use.

Policy drivers and pesticide regulation

The Ministry of Agriculture and Forests (MAF) is responsible for pesticide regulation and utilization in agriculture and forestry. Plant protection products can only be distributed by order of the Minister of Agriculture and Forests. The National Service for Plant Protection (NSPP) organizes, leads and controls the biological testing of plant protection products (PPPs). NSPP prepares a PPPs register and controls the trading and utilization of PPPs. They publish an annual list of PPPs that are permitted for trading and this is available on the MAF website (http://www.mzgar.government.bg/) and NSPP (http://www.nsrz-bg.com).

The National Forestry Board (NFB) with its specialized and regional structures is responsible for the health status of the forests. NFB structures organize all forest protection activities in the state and private forests. Other owners (such as municipalities, religious communities, private companies) are responsible for all forest protection activities for forests under their control.

Weed problems

Major problem weeds encountered in nurseries are: *Amaranthus* sp., *Echinochloa crus calli* L., *Atriplex patula* L. *Setaria* sp., *Solanum nigrum* L., *Datura stramonium* L., *Veronica* sp., *Raphanus raphanistrum* L., *Capsella bursa pastoris* L., *Lamium purpureum* L., *Polygonum convolvulus* L., *Lathyrus* sp., *Portulaca oleracea* L., *Xanthium* sp., *Cynodon dactylon* Pers., *Sorgum halepense* (L.) Pers., *Elytrigia repens* L., *Equisetum arvense* L., *Solanum nigrum* L., *Datura stramonium* L, *Lamium purpureum* L., *Polygonum convolvulus* L. Some members of the *Cuscutaceae* caused damage in *Robinia pseudoacacia*, *Sophora japonica* and *Alnus* sp. seedbeds in some areas.

Treatments and alternatives

Current knowledge

In Bulgaria there are over 300 weed species (Fetvadjieva, 1973). Vatov and Zahov (1980) prepared a list with 81 of the most widespread weed and shrub species in forest nurseries, plantations and natural stands, and a classification based on the biological characteristics of weeds was published by Kazakevich and Malcev (Fetvadjieva, 1973). The annual and perennial wheat and broadleaved weeds are a serious problem for forest nurseries (Vatov and Zahov, 1980).

Methods/strategies adopted for managing weeds in Bulgarian woodlands

These are summarized in Table 12.7. The most common methods of weed control in forest plantations and stands are:

- Cultivation before afforestation: this method/technique depends on the relief, soil condition and existing vegetation.
- Regular clearing in the spaces among young plants until canopy closure. This is done 2–3 times a year, by manual or mechanical methods, over a 3–5 year period.
- Renewing by afforestation under the canopy by preparation of a small part of the area where the weeds, shrubs and other tree species coppices are cleaned by cutting.
- In areas with natural regeneration a thinning of undesirable vegetation is carried out to release desirable tree species.

Mechanical methods

Cutting by machine or hand is a highly satisfactory method for weed control because of the present low labour costs. This is combined with herbicide application.

Cultivation

Cultivation is one of the most commonly used methods for weed control especially where poplar plantations are established. It is also used in the fallow lands in nurseries. Cultivation is combined with herbicide use.

Mulches

Mulches are not used in Bulgarian forest vegetation management. Inorganic plastic sheet mulches are only used in agriculture and organic-based mulches (such as bark or sawdust) are only used in landscaping.

Biological weed control

The planting of Avena sativa L. or Vicia sativa L. cover crops for one year on fallow lands is also used in some forest nurseries as a weed control measure.

Herbicides

Herbicides are the most commonly used method of vegetation management. The main herbicides used in Bulgarian forest nurseries, along with an estimate of annual usage, are given in Table 12.8. According to Vatov and Zahov (1980) the treatment of the stump against unwanted shoots sprout after felling with herbicides will realize savings of 30 % in funds and 80 % in labour costs.

Table 12.7 I Summary of weed types, most common control methods and impacts in Bulgarian woodlands.

Weed Type	Treatment alternatives	Cost (€ ha^{-1}) [a]	Effectiveness	Potential environmental Impacts
Annual and perennial grasses and broadleaved weeds	Herbicides	180–400	Very effective (90–100%)	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Cultivation	50–100	Effectiveness varies with weed and site type.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Thinning of unwanted shoots and shrubs	Cutting	80–100	Effectiveness varies with tree and shrubs species.	Pollution, disruption to ground-nesting birds.
	Cultivation	50–100	Effectiveness varies with site type.	Soil erosion, water sedimentation, pollution, disruption to ground- nesting birds.

Herbicide	Estimated BG annual usage (kg active ingredient)
Glyphosate	15.000
Oxyflorofen	6.200
Raundab	558.700
Fluazifop-p-butyl	0.360
Total	**580.260**

Table 12.8 I Main herbicides used in Bulgarian forestry (during 2006).

Barriers to adopting alternative methods

No information is available at present

Ongoing research

There are no ongoing research projects in this field in Bulgaria, despite the need for increasing the knowledge for weed control in woodlands.

Future research needs / potential for European collaboration

The lack of information in Bulgaria about weed species in woodlands and forest nurseries highlights the need for scientific project work in this field. The increase in labour costs in the near future will make mechanical methods unattractive and expensive.

This, combined with European Union policy to minimize pesticide use as far as possible, will require a search for alternative methods for environmental friendly control of undesirable vegetation. The realization of such future research will help to: increase the effectiveness and to decrease the costs for elimination of weeds in forest nurseries; improve the skills of people working in this sector; update the real costs/prices for nursery management; test alternative methods for controlling undesired vegetation in both nurseries and forest plantations.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Ecosystem responses

Current knowledge

Effects of weeds on trees and nature and magnitudes of effects

No information is available on the effects of weeds on trees and nature and magnitudes of effects.

Impacts of control methods

Impacts are outlined in Table 1.7.

Ongoing research

No information is available about ongoing research.

Future research needs / potential for European collaboration

Research work within the State National Forestry Agency needs to be reported to clarify the relative competitiveness of different weed species, critical periods of weed competition, and the ecology of weed species.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge, ongoing research and future research needs

No information is available at present current/ongoing research. There is a need for research into attitudes and perceptions of risk for forest vegetation management practices and possible alternatives.

Barriers to carrying out future research

No information on barriers is available at present.

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Iceland Photo 7.1 | Sitka spruce *(Picea sitchensis)* under severe competition from grass on former agricultural land.

Iceland Photo 7.2 | Planting after mechanical preparation with a disc trencher.

Ireland Photo 8.1 | Windsnap in John F. Kennedy Aboretum, Co. Wexford, Ireland.

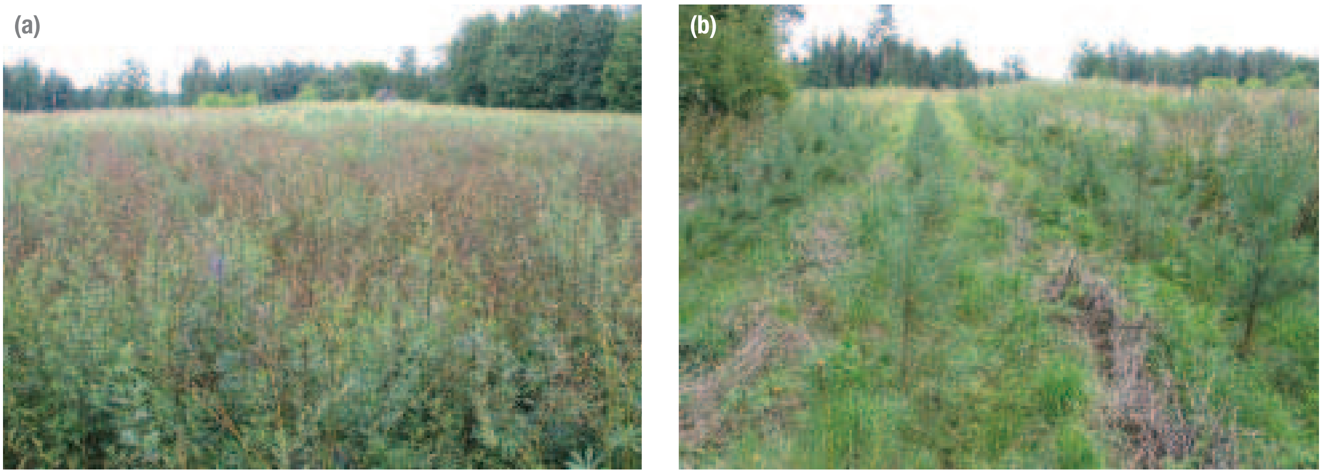
Ireland Photo 8.2 | Weed regrowth 2 years after ploughing and planting with *Eucalyptus* spp. for foliage cuttings in south west Ireland.

Ireland Photo 8.3 | Mulch mat trial on Christmas trees near Clonroche, Co. Wexford. The mulch mats were very effective in controlling weeds but costs were prohibitive.

Italy Photo 9.1 | Experiments on the effect of mulching with raw compost and pine bark on shade tree species.

Italy Photo 9.2 | Coconut fibre and plastic shelters in a renaturalization trial after thinning in a mature plantation.

Italy Photo 9.3 | Use of in-row herbicides plus between-row natural ground cover in an intensive plant production plantation.



Lithuania Photo 10.1 | Three-year-old pine plantations on former agricultural lands: **(a)** no vegetation management; **(b)** after manual cutting of grasses with a hoe.

Norway Photo 11.1 | Natural regeneration is the dominating method for regeneration of pine (Aksel Granhus).

Norway Photo 11.2 | Wavy hairgrass *(Deschampsia flexuosa)* is one of the main weed species invading spruce sites following clearcutting (Aksel Granhus).

Norway Photo 11.3 | **(a)** Weed control in Christmas tree plantations is especially important during the first years following establishment. **(b)** Lack of adequate weed control may lead to reduced quality Christmas trees and also to pathogens in the plantations (Inger Sundheim Fløistad).

Republic of Bulgaria Photo 12.1 | Manual and mechanical weed control in a black pine *(Pinus nigra)* forest nursery seedbed: State Forest Enterprises Belogradchik, Stara Planina mountain, 2007 (Nikolay Stoyanov).

Republic of Bulgaria Photo 12.2 | Mulching in a new forest plantation of *Cedrus altlantica* in Chepelare region, Rodopi Mountain, 2008 (Stefan Yankov).

13

Romania

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Country background

History

Historically, forests have played an important role in Romania's social and economic development, providing a major source of rural employment and income through logging, wood processing and non-timber forest products industries. Between World Wars I and II, and subsequently from 1948 to 1989, forests were over-cut to support industrial development and to generate export revenue. In the 1990s, forest managers reduced the annual timber harvest to levels significantly below the long-term annual allowable harvest to enable the forests to recover. Unfortunately, past over-cutting has left a legacy of large areas of degraded forest land. This negative environmental impact has been compounded by the lack of a suitable forest road network in Romania. As a consequence, nearby, accessible areas have been over-harvested while more remote, inaccessible areas have remained either unharvested or under-harvested.

The process of forest restitution to pre-nationalization owners, initiated after the fall of communism, has significantly impacted on the development of the forest sector in Romania. As an initial measure, under Law 18/1991, approximately 350 000 ha of forest land were returned to around 400 000 pre-1948 individual owners (up to 1 ha per owner). In 2000, land restitution Law 1/2000 was passed by Parliament and its implementation was initiated. According to this law all community, town and communal forests should be restituted to their former owners, with limitations of 10 ha for individuals and 30 ha for churches. According to the third restitution law (Law 247/2005) all forest land should be restituted to pre-nationalization owners (or descendants), thus finalizing, from the legislative point of view, the forest restitution process in Romania.

Although natural-type forests and close-to-nature forestry principles have been highly promoted in the Romanian forestry sector in the past half century, the past decade has been characterized by an emphasis on wood harvesting in many parts of the country (especially in non-state forests). On the other hand, significant steps in biodiversity conservation (including the establishment of administration units for all large protected areas) in parallel with efforts towards the afforestation of degraded agricultural land have also been made in the past decade.

Topography and climate

Romania is the largest country in southeastern Europe with a surface area of 238 391 km^2 and a roughly equal distribution of mountainous, hilly and lowland terrains. The Carpathian Mountains dominate the centre of Romania, with 14 of its mountain ranges reaching above the altitude of 2000 m. In south-central Romania, the Carpathians soften into hills, towards the southern plains.

Because of its position on the southeastern part of the European continent, Romania has a transitional climate between temperate and continental. Climatic conditions are influenced by the country's varied relief. The average annual temperature ranges between 11 °C in the southern plain to 0 °C in the alpine area, while the mean temperature varies from -10 °C to 0 °C in January and 10 °C to 29 °C in July. Rainfall decreases from west to east and from mountains to plains, ranging from a mean annual value of 380 mm on the Black Sea coast to 1200 mm in some alpine areas. The length of the growing season (daily temperature higher than 5 °C) also varies significantly, from 55 days in the alpine area (Omu Peak) to 255 days in southeast and southwest Romania.

Woodland area

Woodlands (forests and other areas with woody vegetation) cover 6.79 million ha or 28 % of the land area of Romania (Table 13.1). Approximately 250 000 ha are considered to be virgin/quasi-virgin natural forests (Biriş and Doniţă, 2002), although not all of them are included in the national network of protected areas.

More than half of the country's forests have been effectively and conservatively managed as *protection forests*, mainly for non-wood production objectives, including watershed management, conservation of seed stands, game management, and research (Tamaş and Abrudan, 2003). Between 11 000 ha and 15 000 ha are naturally regenerated every year while about the same area has been afforested annually in the past decade (Abrudan *et al.*, 2003). The cost of afforestation (including seedling cost) varies between €900 ha^{-1} and €2500 ha^{-1}, depending significantly on the cost of site preparation and the initial density (4000–10 000 seedlings ha^{-1}).

The total area of forest nurseries managed by the National Forest Administration (Romsilva) in 2006 was 357 ha, of which poly-houses occupied 2.1 ha (RNP-Romsilva, 2007). Although there is no accurate information at national level regarding the non-state forest nurseries, the Association of Forest Administrators in Romania estimated that in 2006 the area of non-state nurseries did not exceed 50 ha.

Land use	Area (million ha)	Percentage (%)
Forests and other areas with woody vegetation	6.79	28.5
(includes forest included in the 'forest fund')	(6.37)	(26.7)
Agriculture	14.73	61.8
Water and ponds	0.88	3.7
Other areas/urban	1.43	6.0
Total	**23.83**	**100**

Table 13.1 I Land use in Romania. Source: *Romanian statistical yearbook–2005* (National Statistical Institute, 2006).

Species composition

About 70 % of Romanian forests consist of broadleaves, European beech (*Fagus sylvatica*) being the dominant species (Table 13.2). Oaks, especially sessile (*Quercus petraea*) and pedunculate (*Q. robur*), cover 18 % of the forest area while other native broadleaved species represent less than 5 %. Exotic species have been carefully introduced into the composition of Romanian forests with black locust (*Robinia pseudoacacia*) being by far the most widespread non-native species (occupying more than 100 000 ha).

Conifer forests, predominantly found in mountain regions, are mainly represented by Norway spruce (*Picea abies*), which covers around 21 % of the country's forest area, followed by silver fir (*Abies alba*) at 4 %.

Total forest area	6.3 million ha
Forest ownership (January 2007)	
• State-owned forests	62 %
• Non-state forests	38 %
Forest types	
• Coniferous (especially Norway spruce)	30 %
• Beech	31 %
• Oaks	18 %
• Other	21 %
National forest stock	1350 million m^3
Annual growth	5.4 m^3 ha^{-1} yr^{-1}
Geographical distribution of forests	
• Mountains	65 %
• Hills	27 %
• Plains	8 %
Functional distribution (January 2007)	
• Protection forests (not protected areas)	52 %
• Production forests	48 %

Table 13.2 I Main features of Romania's forests.

Ownership and subsidy regime

Around 62 % of woodlands are publicly owned, but this percentage will decrease as the process of forest restitution to pre-nationalization owners is still ongoing. Compared to the previous decade (1991–2000), when the average rate of afforestation of degraded agricultural land was 345 ha yr^{-1} (Abrudan *et al.*, 2003), the present decade is characterized by a significant increase in the area of afforested agricultural land. For example in 2006 about 3800 ha of degraded agricultural land was afforested by the National Forest Administration (Romsilva) alone.

Although the government has not yet provided afforestation grants, afforestation of degraded agricultural land has become eligible for funding from the so-called 'regeneration and conservation fund' administered by the public authority responsible for forests. Afforestation of private agricultural land might benefit from state support in the future (up to 80 % of the total afforestation costs), as it is included in the National Plan for Rural Development.

By January 2007, 26 large protected areas had been established in Romania. These cover 1.65 million ha and comprise national parks, nature parks and biosphere reserves including the 580 000 ha Danube Delta Biosphere Reserve. They include about 607 000 ha of forests, of which 143 000 ha are strictly protected as special conservation areas. About 39 000 ha of strictly protected forests are also included in the national network of small protected areas, e.g. scientific reserves and nature monuments.

Type of protection	Area (ha)	Percentage (%) of total woodland area
Forests included in special conservation areas (tree felling forbidden)	182 000	2.7
Forests included in legally established protected areas (e.g. national parks, nature parks, reserves)	646 000	9.5
FSC certified forest	1 124 412	16.6

Table 13.3 I Protected woodland areas in Romania. Source: Regia Nationala a Padurilor (RNP) – Romsilva (2007).

Silvicultural systems

Forests in Romania are divided into two functional groups: *production forests* and *protection forests*. Silvicultural practices are based on natural regeneration of native species such as oak, beech and other native deciduous trees in more than 75 % of Romania's production forests. Continuous forest cover forms the basis of extraction systems. The rotation period between stand harvesting is typically 80+ years (with a shorter period for poplars and black locust species). Mature trees are then felled either through individual selection (managed thinning) or by group felling. Clearfelling is limited by law to a maximum of 3 ha and is carried out in pure conifer forests (spruce, pines etc.), black locust and poplar plantations. In protection forests, conservation felling (for sanitation and/or safety) is permitted in areas prone to erosion and landslides, while selection or group selection systems are permitted in other categories of land sensitive to erosion. Restricted application of the shelterwood system is also allowed in some of the functional categories.

Herbicide use and comparisons

The fall of communism at the end of 1989 brought about a reduction in the use of herbicides in forestry compared with the previous period. During 1990–1997 the use of herbicides was extremely low (only in a few forest nurseries and in some plantations) as weed control was done by hand with low cost labour and very rarely mechanized.

After 1997, the National Forest Adminstration (Romsilva), which managed 95 % of the entire forest area at that time, decided to increase the use of herbicides for weed control, especially in forest nurseries, but also in some young plantations. This was mainly due to the reduction in availability of low cost labour and the provision (acquisition) of suitable cultivation equipment. Yet the use of herbicides in state forests – both in forest nurseries and young plantations – is now significantly lower than in the period before 1989, partly because the transfer of forests in non-state hands due to the restitution process has contributed to a reduction in herbicide use for weed control. The total annual quantity of herbicides used in Romanian forestry has been estimated at 10 tonnes of active ingredient, which is very low considering that woodlands cover 28.5 % of the country's area (Table 13.4).

Crop	Total area crop (ha)	% Land area	Area treated (ha)	% Area of each crop treated	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides	6 374 000	26.7	4 320	0.07	9.608	n/a
Forestry insecticides	6 374 000	26.7	43 000	0.69	1.191	n/a
Total forestry pesticides	6 374 000	26.7	47 320	0.76	10.799	n/a

n/a: not available

Table 13.4 | Pesticide usage on different crops in Romania. Source: Regia Nationala a Padurilor (RNP) – Romsilva (2007).

Policy drivers and pesticide regulation

Conservation and sustainable management of Romanian forests are controlled by the Forest Law and other forestry sector regulations. In the context of EU accession, Romania changed all regulations on the use of herbicides, avoiding the use of those with high toxicity and, where possible, increasing biological control methods. Biological products based on BTK (Bacillus Thuringiensis Kurstaki) and NPV (nuclear poliedrosis virus) are used for insect control. Approximately 17 % of Romanian woodlands are FSC certified (Table 13.3). Owners/administrators of certified forests have been asked to develop a strategy which will lead to replacement, reduction and eventual elimination of all synthetic pesticides.

Weed problems

The main weed types impacting on the survival of young naturally regenerating or planted trees vary according to the forest site and species, but they are mostly grass and herbaceous species. In a very few situations, for example in poplar hybrid plantations, established in the Danube floodplain, some woody species such as indigo bush (*Amorpha fruticosa*) and grey bramble (*Rubus caesius*) are invasive.

In young conifer plantations and also in some broadleaf plantations species such as birch (*Betula pendula*), aspen (*Populus tremula*) and goat willow (*Salix caprea*) can affect or even compromise the regeneration of the main forest species if they are not controlled in time. Also in some natural beech regeneration, species like lime (*Tilia* sp.) and common hornbeam (*Carpinus betulus*) can become dominant and affect the composition of such forests, while in oak plantations, grey bramble together with grass and herbaceous species can seriously compete with the oak.

With the exception of poplar, black locust and some conifer forests, where clearfelling is permitted, silvicultural methods are mostly based on natural regeneration. Depending on the type of woodlands, forest species compete with weeds to varying degrees. Therefore the present regulations and guidelines related to forest regeneration stipulate a certain number of manual weedings and/or cultivations (both manual and mechanized) per year, from the year of establishment to canopy closure, according to site conditions and the main forest tree species in the forest composition (MAPPM, 2000a,c).

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Romanian woodlands

These management methods and strategies are outlined in Table 13.5.

Silvicultural systems

Since 1976, planting of native species specific to the natural type of forests, expansion of natural regeneration, continuous cover forestry and restoration to native species of conifer plantations established outside their natural distribution area have been highly promoted as principles in Romanian forest management (Abrudan, 2006). As a consequence, the use of herbicides has been reduced compared with what was required for clearfell–replant systems. However, their use is still required in some areas where clearfelling is still carried out (poplar, black locust and some conifer forests).

Mechanical methods

Although the cost of labour is higher than the cost of herbicides, techniques such as manual weeding (by pulling and cutting) are common in young conifer plantations (Photo 13.1, page 153). From the administrators' point of view these are more environmentally friendly methods. Manual weeding is also common in natural regenerations. According to the Romanian technical norms (MAPPM, 2000a,b) 1–2 manual weedings are carried out annually in young conifer plantations from the year of establishment to the age of 5–9 years (depending on species composition and site conditions).

Cultivation

Cultivation is a common method of weed control, especially in young broadleaf plantations (e.g. oaks, maple, ash, lime, black locust, poplar, willow) several years after the establishment of forests. Cultivation relieves soil compaction and in many situations it controls weeds effectively. According to the Romanian technical norms (MAPPM, 2000a) 1–4 cultivations are done annually in young broadleaved plantations/natural regenerations from the year of establishment to the age of 4–8 years (depending on species composition and site conditions). Where possible, these cultivations are mechanized between the rows of seedlings (Photo 13.2, page 153) and manually by hand hoe around the seedlings.

Mulches

The use of various types of mulches in young plantations was intensively researched in Romania in the early 1990s (Costăchescu, 1991). However, mulches are not used in young plantations in Romania due to the high cost and impracticability in many situations, despite the fact that some local low-cost mulches like moss or straw are used in forest nurseries.

Biological weed control

There is no known research and practical steps towards the use of biological weed control in Romanian forestry.

Herbicides

As already indicated the use of herbicides is an alternative but not commonly used method for vegetation management in young plantations in Romanian forestry. Glyphosate is the main herbicide, while simazine may also be used in some cases (Mihăilă, 2005). The herbicides used in forest nurseries along with an estimate of annual usage are presented in Table 13.6.

Table 13.5 | Summary of weed types, commonest control methods and impacts in Romanian woodlands.

Weed type	Treatment alternatives	Cost (€ ha^{-1}) [a]	Effectiveness	Potential environmental impacts
Grasses	Manual and mechanical weeding	56–507	Some weeds may multiply. Medium effective.	Some seedlings may be accidentally affected, hurt or even cut, favouring pest and fungus infestation.
	Cultivation	990–3960	Effectiveness varies with weed and site type.	Soil erosion, water sedimentation, pollution.
	Herbicides	45–450	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
Herbaceous weeds	Manual and mechanical weeding (cutting)	56–507	Some weeds may multiply. Medium effective.	Some seedlings may be accidentally affected, hurt or even cut, favouring pest and fungus infestation.
	Cultivation	990–3960	Effectiveness varies with site type.	Soil erosion, water sedimentation, pollution.
	Herbicides	45–450	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
Indigo bush, bramble	Cutting	145–1305	Weakens rather than kills.	Some seedlings may be accidentally affected, hurt or even cut, favouring pest and fungus infestation.
	Herbicides	45–450	Very effective when it is not completely developed.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Cultivation	990–3960	Only deep ploughing effective.	Soil erosion, water sedimentation, pollution.
Woody weeds	Cutting	145–1305	Weakens rather than kills.	Impacts on forest composition, and largely on biodiversity.

[a] Lowest cost is for one-off control, highest cost for repeated control until tree establishment. For comparison purposes, costs refer to the expense of treating 100% of the area of 1 ha of ground over a 5-year establishment period. If spot or band weeding were practised, costs would reduce accordingly. In some cases manual and mechanical weeding (cutting) and cultivation are carried out alternately.

Herbicide	Estimated Romanian annual usage (kg active ingredient)
Glyphosate	100
Oxyfluorfen	5
Simazine	6000
Atrazine	100
Imazetapyr	10
2,4-D	20
Cyanazine	430
Quisalofop-p-tefuryl	50
Clopyralid	20

Table 13.6 | Main herbicides used in Romanian forestry.

Barriers to adopting alternative methods

As previously mentioned herbicides are used only rarely in Romanian forestry. Low labour costs have stimulated the use of mechanical weed control but now due to the rapid increase in these costs in Romania there is a clear interest in developing more advanced, low-cost mechanical methods.

The replacement of insecticides with biological product treatments has been intensively promoted in Romanian forestry in the past decade. Also, due to the FSC certification progress, it is estimated that the use of pesticides will decrease. The integration of information about individual pest, disease, vegetation and wildlife problems would be a better approach to the problems of reducing pesticide usage, and should lead to the identification of the management method which has the lowest impact on the environment.

Ongoing research

Due to the low usage of pesticides in Romanian forestry only limited research on this topic has been carried out recently (mainly testing of new pesticides). However research on indigo bush control is currently ongoing, as this invasive species is a strong competitor in poplar plantations.

Future research needs/potential for European collaboration

Research is needed on the development of biological herbicides with reduced or no impact upon the environment as a solution to the problem of using synthetic herbicides, and it requires European collaboration. Also, research on biodegradable mulch materials may be necessary, especially for urban forestry or roadside plantation situations.

Barriers to carrying out future research

The limited funding for research is a common issue for many European states, including Romania. Another problem, specific to Romania, is the poor dissemination of information on vegetation control methods among forest owners and administrators.

Ecosystem responses

Current knowledge

Effects of weeds on trees

The competition between weeds and forest species for light, water and nutrients results in the weakening of seedlings (low growth) and can affect seedling survival, especially in southern Romania which is characterized by hotter and drier sites. This affects the cost of vegetation establishment due to replanting (Mihăilă, 2000). Reduction in tree growth, quality and survival as a consequence of weed competition is also affecting the length of time from establishment to canopy closure.

Nature and magnitudes of effects

There is no co-ordinated research at a national level on this topic. However, in the case of invasive species, the composition of natural and semi-natural ecosystems can be changed significantly. For example, indigo bush became dominant on a large scale on sites naturally occupied by floodplain forests (mainly *Salix* sp. and *Populus* sp.) on the Small Island of Braila in southeast Romania (Abrudan *et al.*, 2003).

Impacts of control methods

Potential environmental impacts are outlined in Table 13.5.

Ongoing research

The use of more vigorous or container-grown seedlings can be an option to reduce herbicide use, especially in the areas where weed competition is very high and this alternative might be cost-effective (Muşat and Muşat, 1992). Research into integrated vegetation management technologies and agroforestry cultures (agricultural crops between the seedlings rows, especially in the plain regions) has been carried out to find a suitable, low-cost alternative to herbicide usage.

Future research needs/potential for European collaboration

A thorough study of the biology, ecology and competitive effects of invasive species may help in forest vegetation management practices in Romania. Also a study of the relationships between weeds and tree seedlings under different silvicultural treatments on different sites might be useful for forest practice.

Barriers to carrying out future research

For Romania the poor funding and the low priority of this topic compared to others are the main barriers to carrying out future research. Also, forest restitution to previous owners narrows the research base as the owners' interest in this topic is low.

Society and vegetation management

Current knowledge

Unfortunately society is not aware of forest vegetation management, partly because of the lack of specific projects to communicate the work. The social dimensions of vegetation management within woodlands in Romania are neglected. The current low-scale herbicide usage is mainly the result of cost compared to cheaper alternative methods of weed control.

Ongoing research

There is no ongoing research on this topic.

Future research needs

Society should be informed about the forest as a whole and also about forest vegetation management practices and possible alternatives. Forest regulations regarding forest management should be explained to private owners in order to reduce the negative impact on trees and the environment.

Barriers to carrying out future research

Lack of funding and low priority compared to other forestry topics such as forest restitution, biodiversity conservation and biomass production are barriers to future research.

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14 Serbia

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Country background

History

As far back as 1332, the writer Adam Guion travelling through Serbia described it as a country rich in large and immense forests. La Martin in 1833 travelled through the dense oak forests of Šumadija (a region in central Serbia), and compared them to the forests of North America. The first written data on the growing stock in Serbia (1884–1885) quote 208 000 ha of state-owned forests, 262 000 ha of community and public forests and 748 000 ha of rural and municipality forests, giving a total forest area of 1 218 000 ha; a later assessment of the overall growing stock was 1 546 000 ha. The development of the idea of sustainable management started as far back as the Czar Dušan's Law in 14th century which introduced a ban on clearing. In 1821, aware that the forests were being cleared without justification, Prince Miloš issued an order which prohibited forest clearing in order to protect the resource for acorn feeding for livestock and for fuelwood. The hazards of clearcutting were also emphasized by the academician Josif Pančić in 1856 in his description of the waterless barren regions of the west slopes of Kopaonik and Raška.

Taking into account the need for a radical change of attitude towards forests, and because previous state regulations, orders and decisions had not had sufficient effect on the harmful practices in forests, the National Assembly passed the first Forest Law in 1891; this was really the start of practical organized forest management in Serbia. The law primarily addressed the halting of deforestation and clearcutting. It prescribed rules for harvesting and regeneration for all forests, regardless of ownership, for the common good of the country.

After World War I, and during and after World War II, forest exploitation was an intensive and profitable economic activity. Together with ore extraction, forests were the major supporters of economic welfare in Serbia. Their role during that period was therefore exclusively economic. Hence both forest stability and the principle of sustainable management of stands became endangered by overfelling. This concern led to the establishment of the Fund for Forest Enhancement in 1955. Since then the principle of sustainable management, manifested in Czar Dusan's law has been applied. This is carried out by management based on expertise and sound scientific principles (Forestry Development Strategy for the Republic of Serbia, 2006).

Topography and climate

Serbia's terrain is very varied, with fertile Danubian plains in the north, huge mountain ranges and hills in the southeast, and in the central area hills, mountains, rivers and creeks. Among the geographical features that influence the climate of Serbia are the Alps, the Mediterranean Sea and bay of Genoa, the Pannonian Plain and the valley of Moravia, the Carpathian and Rodopi mountains, as well as the hilly-mountainous areas, ravines and highland plains. The location of river ravines and plains in the northern area of the country allows deep southward intrusion of polar air masses in the winter.

Average annual air temperatures (for the period 1961–1990) vary according to altitude: 10.9 °C in areas up to 300 m; 10.0 °C in areas of 300–500 m; 6.0 °C in areas over 1000 m. Absolute maximum temperatures in the period 1961–1990 were measured in July and range from 37.1 to 42.3 °C in lower regions, while the absolute minimum measured in January in mountainous areas range from -35.6 to -20.6 °C. Average annual precipitation increases with altitude: 540–820 mm in lower regions; 700–1000 mm in areas over 1000 m; and up to 1500 mm in some mountainous summits in southwestern Serbia. Most of Serbia experiences a continental precipitation regime with higher quantities in the warmer months, except for the southwest where highest levels occur in autumn. June is the rainiest with an average of 12–13 % of the total annual precipitation while February and October have the least.

Woodland area

Forests and forest land occupy 2 360 000 ha in Serbia (Table 14.1). The percentage forest cover is 26.7 % which is slightly lower than the average percentage forest cover in Europe (29 %) and in the rest of the world (30.3 %). The Spatial Plan (managed by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia) predicts an increase in forest cover percentage from the present 26.7 % to 31.7 % by 2010, and to 41.4 % by 2050. Based on changes in the Law on Agricultural Land, it is possible to convert the poorer categories of agricultural land into forest land; in addition another 90 000 ha of forests can be obtained by shelterbelt establishment in Vojvodina Province in northern Serbia. By increasing the forest cover percentage to the desired level, i.e. the required level, Serbia would then join the group of European countries with higher forest cover. In this way, the global goal of sustainable forest management and governance would be realised and be more appropriate for the present and future demands of a more uniform balance between natural resources protection and conservation and multiple uses of forest ecosystems.

Table 14.1 | Land use in Serbia.

Land use	Area (ha)	Percentage (%)
Forests	2 360 000	26.7
Agriculture	5 734 000	65.5
Urban/other	693 000	7.8
Total	**8 840 000**	**100**

During 2006, 1432 ha were afforested, more than 3 million seedlings were planted (753 ha in private ownership, 451 ha of state lands, 115 ha of forest plantations) and 113 ha of burnt areas were reclaimed. Free seedlings are given to private forest owners for the afforestation of their holdings, and professional instructions for planting are provided by the professional services of State Enterprises in charge of private forests. Afforestation plans for another 3630 ha of new plantations are in preparation for 2008; this comprises 1400 ha of private land, 1130 ha of state-owned land, and reclamation of 1100 ha of burnt areas. To meet this aim, more than 9 million forest seedlings have already been produced and it is expected that funding will be granted (Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, 2007). To realise the establishment of 100 000 ha of new forests by 2015, about €8 750 000 per annum will be required, based on present market trends and previous experience. Average establishment cost is €1500 ha^{-1}.

General species composition

Broadleaves make up 90.7 % of the forests in Serbia, with beech accounting for 27.6 %, oak 24.6 %, poplars 1.9 %, other broadleaves 6.6 % and mixed broadleaf stands 30 %. Conifers account for 6 % and mixed forests of broadleaves and conifers 3.3 %. These data refer to the state-owned forests in Serbia; insufficient data are available on the composition of privately-owned forests (Forestry Development Strategy for the Republic of Serbia, 2006).

Ownership

As indicated, there are two types of forest ownership in Serbia – private and state. The area of private forests and forest lands accounts for 48.6 % and they are not subsidized by the state. The area of state-owned forests, of which the majority is entrusted by law to State Enterprises ('Srbijasume' and 'Vojvodinasume'), and the balance to National Parks and other state-owned institutions, accounts for 51.4 % (Table 14.2).

Table 14.2 | Forest ownership in Serbia.

<table>
<tr><th>Land use</th><th>Area (ha)</th><th colspan="2">Area (ha)(%)</th><th>Percentage (%)</th></tr>
<tr><td rowspan="2">State-owned forests</td><td>National Parks and other protected areas</td><td>513 075</td><td rowspan="2">1 215 000</td><td rowspan="2">51.4</td></tr>
<tr><td>State Enterprises (Vojvodinašume and Srbijašume)</td><td>701 925</td></tr>
<tr><td colspan="2">Private forests</td><td colspan="2">1 145 000</td><td>48.6</td></tr>
<tr><td colspan="2">Total woodland area</td><td colspan="2">2 360 000</td><td>100</td></tr>
</table>

Some areas are subject to special protection measures. The main goals of this protection are diversity conservation and enhancement of biodiversity, geo-heritage phenomena, landscapes, environmental quality, sustainability and quality of natural resources and spaces. The Spatial Plan of the Republic of Serbia defines the basic goals of protection. It is expected that the percentage of protected areas of special natural values will reach 10 % of the land area of Serbia by 2010 (Jancic and Zelic, 2007). Table 14.3 shows the different forms of protection in Serbia: 419 protected areas covering 5 130 025 ha or about 6 % of the land area of Serbia.

Type of protection	Number	Area (ha)	Percentage (%)
National Park	5	158 986	31.0
Park of nature	8	228 055	40.4
Regional park of nature	10	24 200	4.71
Park forest	20	273	0.05
Landscapes of specific form	8	18 897	3.68
Special nature reserves	6	73 428	14.31
Nature reserves	84	3 791	0.73
Monuments of nature	247	3 117	0.60
Memorial natural monuments	31	2 328	4.53
Total	**419**	**513 075**	**100**

Table 14.3 | Protected areas in Serbia.

Herbicide use and comparisons

The use of herbicides as a weed control measure in forestry is becoming increasingly important. Weeds have multiple unfavourable effects which are reflected in a decrease in quality and quantity of wood products and planting stock. Weeding requires large financial and labour inputs, both of which increase the total cost of production. The application of herbicides reduces the spread of weeds, especially in the initial phases of forest seedling development when the unfavourable impact of weeds is highest. Improved economic effects in the production process are achieved simultaneously. The total consumption of pesticides in forestry in Serbia amounts to 32.58 tonnes of which 24.84 tonnes are herbicides (76.24 %), 3.85 tonnes are fungicides and 3.89 tonnes are insecticides (Table 14.4). Data on pesticide consumption in agriculture were unavailable.

Pesticides	Quantity of product (tonnes)	Percentage (%)
Herbicides	24.84	76.24
Fungicides	3.85	11.83
Insecticides/rodenticides	3.89	11.93
Total applied pesticides	**32.58**	**100**

Table 14.4 | Pesticide usage in forestry of Serbia.

Policy drivers and pesticide regulation

In Serbia the marketing of pesticides is regulated by the provisions of several regulations issued by the Ministry of Agriculture, Forestry and Water Management, the Ministry of Health and the Ministry of Environmental Protection. Based on the Law on Plant Protection, the Ministry of Agriculture, Forestry and Water Management and all those entrusted with forest management are obliged to monitor and inform the authorized organizations on the occurrence and degree of infestation of harmful organisms, with the aim of suppressing and preventing their spread. This law addresses plant protection against harmful organisms, health control of plants in internal and transboundary trade, as well as the trade of products for plant protection and plant nutrition.

In order to obtain FSC (Forest Stewardship Council) certification, the present state of forest management system was assessed by the independent certifiers. The report on the evaluation of forest management by SE ‘Vojvodinašume’ by the certification body is expected soon. It is anticipated that significant forest areas may be certified in the future which will require the avoidance of pesticides which are on the FSC list of pesticides prohibited for use in forestry (FSC Pesticides Policy, 2007).

Weed problems

Due to wide inter-row spaces and open canopies in the early phases of development, forest nurseries are ideal places for the development of rich and diverse weed flora (Photos 14.1a and b, page 153; 14.2, page 154). Perennial weeds present the greatest problems; they are difficult to suppress by mechanical means as this often stimulates them to grow and disperse even more intensively, for example a new plant can emerge from each cut rhizome. Species such as aleppo grass *(Sorghum halepense)*, field bindweed *(Convolvulus arvensis)* and couch grass *(Cynodon dactylon)* therefore cause great problems not only in agriculture, but also in nursery production of forest planting materials. In addition to vegetative reproduction, they also reproduce by seeds, enabling them to invade large areas very rapidly.

In poplar plantations (Photo 14.3, page 154) and in naturally regenerated forests, woody weeds such as black elder *(Sambucus nigra)* and hawthorn *(Crataegus monogyna)* develop in addition to herbaceous weeds. Woody weeds are very resistant and have great regeneration capacity, making them practically impossible to destroy by mechanical means.

Not all ground layer plants in forest stands are harmful; in fact they can be classified into useful, indifferent and harmful. Useful plants include edible, medicinal species. Indifferent plants are those which, thanks to their individual presence, low degree of coverage and short vegetation period, do not cause major damage. Harmful plants which cause major damage include many species, the most frequent being old man's beard *(Clematis vitalba)*, common ivy *(Hedera helix)*, honeysuckle *(Lonicera carifolium)*, dewberry *(Rubus caesius).*

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Serbian woodlands

Methods and strategies for weed management are outlined in Table 14.5.

Silvicultural systems

As significant areas of forests become designated as protected areas, their management goals change, i.e. from wood production to diversity conservation and enhancement. This leads to significant reduction in the use of pesticides, because the management goal in these forests is not timber production.

Mechanical methods

Mowing is one way of suppressing established weeds and preventing their seed dispersal. Multiple mowings exhaust the food stores in the root and the plant is killed. Pruning of shoots and stump shoots in plantations is relatively expensive, as it involves considerable manpower. It may also be inefficient if the weeds have a strong regeneration capacity, necessitating repeated mowing and pruning. In plantations, the suppression of weeds within the row or around the young plants is usually done by preparations based on glyphosate while inter-row weeds are suppressed by mowing or weed cutters.

Cultivation

Along with the basic methods of soil cultivation (e.g. ploughing, disking and tilling), hoeing and farrowing are done regularly in forest nurseries and plantations during the growing season and particularly throughout spring and early summer. Hoeing and farrowing is also very beneficial in the maintenance of soil structure, enabling optimal water and air regimes in the soil layer in which the root system develops (Roncevic *et al.*, 2002). The amount of hoeing and farrowing required depends on the soil preparation before the establishment of nurseries or plantations, on soil properties, climate conditions and on the types of weeds present. Mechanical measures aim to maintain water and air regime in the soil and to suppress the potential weeds.

Table 14.5 | Summary of weed types, commonest control methods adopted and impacts in Slovakia's woodlands.

Weed types	Treatment alternatives	Cost (€ ha^{-1})	Effectiveness	Potential environmental impacts
Grasses	Herbicides	50–100	Very effective	Potential polluters depending on the herbicide applied and the environment in which it occurs (water, soil)
	Mulches	150–190	Effectiveness varies with weed/site	No adverse effect on the environment
	Cultivation	600–820	Only effective on annual weeds	No adverse effect on the environment
Herbaceous weeds	Herbicides	30–100	Very effective	Potential polluters depending on the herbicide applied and the environment in which it occurs (water, soil)
	Cutting	100–200	Only effective on annual weeds	No adverse effect on the environment
	Cultivation	150–190	Effectiveness varies with weed/site	No adverse effect on the environment
	Mulches	600–820	Only effective on annual weeds	No adverse effect on the environment
Woody weeds	Herbicides	60–120	Very effective	Potential polluters depending on the herbicide applied and the environment in which it occurs (water, soil)
	Cutting	100–200	Not effective	No adverse effect on the environment

Mulches

Covering the soil with different materials, such as straw, hay, stubble, plastic foils, to prevent weed growth is used on small areas, mainly in forest nurseries. Plastic foils of various colours and thicknesses are the most frequently used.

Biological weed control

In Serbia biological weed control has not been applied in forestry to date.

Herbicides

In contrast to agriculture, the application of herbicides in forestry in Serbia started much later. It is mainly based on the experience from intensive agricultural production; and the research results from agriculture are subsequently applied in forestry. Table 14.6 lists the herbicides most often used in forestry, as well as the quantities applied.

Table 14.6 | Main herbicides used in Serbian forestry.

Herbicides	Estimated annual usage (l or kg of product)
Glyphosate	20 775
Pendimethalin	115
Promethrin	91
Acetochlor	162
Fluroxypyr	491
Triclopyr	863
Nicosulfuron	550
Fluazifop-p-butyl	87
Propaquizafop	56
Diquat	95

Barriers to adopting alternative methods

There are several methods of weed control in use in forestry at present. However, due to the shortage of manpower, high labour prices and large forest areas, the application of herbicides is increasing. Herbicides are cheap and effective and avoid mechanical damage to seedlings that can result from operations such as cutting. In addition, mechanical methods are usually not effective in the early stages of plant development because they fail to reduce competition for soil moisture. Soil tilling is an old method but it only suppresses annual weeds and perennial weeds growing from seed. Mechanical measures are not efficient for perennial weeds, i.e. those developing from rhizomes. Also, woody weeds are very resistant and have high regeneration capacity, making it difficult to destroy them completely by mechanical means. Mulching is practised on a small scale, mainly in forest nurseries. This method is effective against annual weeds, but it has no effect on the suppression of many perennial species. It is also expensive compared to other measures of weed control (Table 14.5).

The application of biological weed control has some limitations, along with a series of advantages. Cultivated crops can be protected against some but not all weeds. It is impossible to destroy the weeds completely, because the survival of biological agents depends on weed presence. It is also necessary to use a biological agent which destroys only weeds and does not affect the cultivated crops. It is therefore difficult to programme the biological protection against weeds with certainty for numerous cultivated species (Konstantinović, 1999).

Ongoing research

The Institute of Lowland Forestry and Environment has recently been investigating the efficiency and selectiveness of herbicides in forest nurseries and plantations, i.e. researching herbicides which are efficacious in weed control but safe for the seedlings of forest trees. The research is also focused on the herbicides which are characterized by favourable eco-toxicological properties and are not hazardous to the environment.

Future research needs

Future research will study the effects of weeds and the control of invasive species such as common milkweed *(Asclepias syriaca)*, common ragweed *(Ambrosia artemisifolia)*, annual fleabane *(Stenactis annua)*, horseweed *(Erigeron canadensis)* as their spread has been rapid in recent years, especially in forest plantations. Research will also focus on the reduction of herbicide application, and the introduction of alternative methods of weed control in forestry.

Barriers to carrying out future research

A barrier to future research could be the lack of financial means.

Ecosystem responses

Current knowledge

Effects of weeds on trees

Weeds grow fast, so young forest plants are deprived of their living space, they are shaded and suffocated and their water and nutrients are diminished. As a result the growth of forest seedlings is slowed down, chlorosis develops and resistance to plant diseases and pests is decreased. Parts of branches or crowns die down and, if the weeds are vigorous, the entire plant can be killed (Zekic, 1983). The impact of weeds in nursery production is even more unfavourable: if weeds are not suppressed, the seedlings are of poorer quality and their number is lower than expected.

Nature and magnitude of competitive effect

Good knowledge of weed biology and the effects of weeds on cultivated plants is very important; in this way adequate measures of weed control can be applied.

Impacts of control methods

The impacts of weed control measures on the environment (water, soil, biodiversity) can be diverse and depend primarily on the environmental situation and application methods used. During herbicide application part of the preparation reaches the leaves and other plant parts, while the remainder reaches the soil and possibly water courses via underground water (e.g. atrazine). The fate of herbicides depends significantly on the environment in which they remain after application. Mulching, i.e. covering with foils, often leads to soil compaction. Also, forest seedlings are sensitive to mechanical injuries inflicted by hoeing. Weeding often damages plants,especially in seedbeds where many seedlings are destroyed along with weeds.

Ongoing research

Work is ongoing on the effect of herbicides on the microbiological activity of the soil in forest nurseries and plantations.

Future research needs

To study the consequences of herbicide use in particular environmental conditions and to determine their properties and behaviour in different biological systems and environments, it is necessary to monitor the fate of molecules following different application methods. One of the analytical methods to be applied in the future is gas chromatography, which enables the separation and qualitative determination of pesticides and their metabolites.

Barriers to carrying out future research

Potential problems in pesticide analysis concern the equipment and methods used in some laboratories in Serbia (Janjic, 2005).

Society and vegetation management

Current knowledge, ongoing research and future research needs

So far, there is no research which specifies the social dimension of the methods of weed control and there is no ongoing research of this type in Serbia. Although no research has been planned, it would be desirable in the future.

Barriers to carrying out future research

A barrier to future research could be the lack of financial means.

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15 Slovak Republic

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Country background

History

The first regulations to protect forests and stop deforestation in Slovakia appeared at the beginning of the 15th century. The main reason to protect forests was to secure wood supplies for the mining and metal industries. The first substantial regulation, 'Maximilian's Forest Act', was issued by emperor Maximilian II in 1565. Harvesting was regulated to clearcuts with reserved trees to produce seeds for forest regeneration following cleaning of the harvesting area. However in the 16th century immigrants from East Carpathian Mountains introduced sheep breeding and sheep pasturage (known as pasturage colonization) to mountain areas. Consequently, for centuries, mountain forests and dwarf pine above the treeline were removed to extend pastures for herds.

In 1769, Maria Theresa of Austria issued the Forest Act for the Hungarian Kingdom, which acted as a precursor for the beginning of modern forest management in Slovak territory. New approaches were brought into practice at the beginning of 19th century in the central part of today's Slovakia. Systematic artificial regeneration and modern harvesting regulations were implemented into forestry practice and sustainable work opportunities in the rural region were ensured. Pasture in the forest was limited by the Act as well as by ownership rights but it was permitted again after World War I, in 1920. Forest pasture was entirely banned in 1960, and since that time there have been various reforestation efforts to broaden the dwarf pine zone and reforest some pastures in mountain areas for nature conservation and avalanche protection.

Topography and climate

Geographically, Slovakia is a very diverse country. The west and north of Slovakia is formed by the arc of the Western Carpathians while southern parts are dominated by vast lowlands. This diversity of natural conditions and physical landscape is also reflected in local climatic conditions that vary considerably between particular regions. A large part of the country's surface is covered by highlands and mountains. These topographic features form an estimated 60 % of the country's area. The remaining 40 % consist of lowlands. The altitude ranges between 94 and 2655 m a.s.l. In a broader European context, Slovakia's territory belongs to a sub-montane to montane type of landscape.

Slovakia belongs to a moderate climatic zone with climate significantly influenced by both altitude and topography. The western part of the country is more influenced by the Atlantic Ocean whereas the eastern regions are under the influence of a continental climate. The average annual temperature in lowland regions varies between 9 and 10 °C while highest mountain locations (> 2500 m) record a sub-zero average of -3.7 °C. The average temperature decreases by 0.5 °C for every 100 m of altitude. Average annual precipitation for the entire country is 743 mm: 65 % evaporates and the remaining 35 % is runoff. Snow cover is not stable and there are many years in which lower regions experience no permanent snow cover at all. Hours of daylight vary: southern regions experience an estimated 2000 hours whereas in northwestern parts this figure is down to around 1600 hours.

Forest area, category and ownership

Forests cover about 41 % of the area of Slovakia (Table 15.1). The country's average growing stock is 231 m^3 ha^{-1}. The average productivity of the country's growing stock is 6.14 m^3 ha^{-1} yr^{-1}. A year-on-year increase in the demand for forest ecosystem services has led to a gradual decrease in the area of commercial forest stand area. Their area has reduced in favour of protection and special-purpose forest which provides multiple social and environmental benefits (Table 15.2).

Land use	Area (ha)	Percentage (%)
Forests	2 007 142	41
Agriculture	2 428 899	49.5
Urban/other	467 532	9.5
Total	**4 903 573**	**100**

Table 15.1 I Land use in Slovakia.
Source: www.statistics.sk

Forest category	Area (ha)	Percentage (%)
Commercial	1 304 760	67.5
Protection	328 526	17.0
Special purpose	298 763	15.5
Total	**1 932 049**	**100**

Table 15.2 I Forest stand category area.
Source: Moravčík *et al.* (2007).

Forestry ownership is outlined in Table 15.3.

Subject	Area (ha)	Percentage (%)
State	794 047	41.1
Non-state	1 032 680	53.4
Unknown	105 322	5.5
Total	**1 932 049**	**100**

Table 15.3 I Structure of forest ownership.
Source: Moravčík *et al.* (2007).

One of the main characteristics of Slovakian forests is their natural diversity. Table 15.4 shows the eight basic forest vegetation zones into which they are grouped.

Table 15.4 I Forest vegetation zones. Source: Moravčík *et al.* (2007).

Vegetation zone	Area (ha)	Percentage (%)	Altitude (m a.s.l.)	Annual precipitation (mm)	Average annual temperature (°C)
Oak	140 167	7.3	below 300	600 and less	8.5 and more
Oak–beech	265 246	13.7	200–500	600–700	6.0–8.5
Beech–oak	457 480	23.7	300–700	700–800	5.5–7.5
Beech	401 880	20.8	400–800	800–900	5.0–7.0
Silver fir–beech	419 337	21.7	500–1000	900–1050	4.5–6.5
Spruce–beech–silver fir	186 365	9.6	900–1300	1000–1300	3.5–5.0
Spruce	41 323	2.1	1250–1550	1100–1600	2.0–4.0
Dwarf pine	20 251	1.1	1500 and more	1500 and more	2.5 and less
Total	**1 932 049**	**100**			

Tree species composition

Forests in Slovakia are dominated by broadleaved species (59 %); spruce is the most common coniferous species (Table 15.5).

Species	Percentage (%)
Beech	31.2
Oak	10.9
Hornbeam	5.7
Other broadleaved	11.4
Spruce	26.1
Pine	7.2
Silver fir	4.0
Other coniferous	3.5
Total	**100**

Table 15.5 I Forest tree species. Source: Moravčík *et al.* (2007).

Forest regeneration

Artificial regeneration has decreased in Slovakia during the past 15–20 years (Table 15.6). The average establishment cost is about €1500 ha^{-1}.

Table 15.6 I Development of forest regeneration (ha). Source: Moravčík *et al.* (2007).

Type of regeneration	Year				
	1990	2000	2004	2005	2006
Artificial regeneration (ha)	15 500	12 923	8 866	8 922	9 256
Natural regeneration (ha)	3 454	2 134	5 094	4 582	6 305
Total regeneration (ha)	18 964	15 057	13 960	13 504	15 561
Proportion of natural regeneration (ha)	18.2	14.2	36.5	33.9	40.5

Weed control

The consumption of pesticides in agriculture has decreased considerably since the beginning of the 1990s. While it was 7.68 kg ha^{-1} of farmland in 1980 and 5.39 kg ha^{-1} in 1985, it dropped to 1.01 kg ha^{-1} in 1992. This means an 87 % reduction compared to 1980. Consumption per hectare of farmland increased slightly after 2000 but has not exceeded the maximum of 2 kg (0.6–0.7 kg of active substance) ha^{-1} of farmland (Ministry of Agriculture Slovakia Republic, 2002).

The decrease in the use of pesticides followed the change in management and land tenure after 1989. It included increased prices of inputs while prices of agricultural products remained unchanged, reduced subsidies, restitution of private land ownership and disappearance of many larger, formerly state- and collectively-owned farms due to privatization and management failures. Thus this reduction in use of pesticides has not been environmentally motivated but it has resulted in a considerably lower pesticide load on agricultural lands and water catchments.

With regard to the categories of pesticides, the most notable decreases between 1991 and 2000 were observed in the insecticides by 72 % (-1364.3 tonnes), herbicides by 32 % (-1012.7 t) and fungicides by 57 % (-630.9 t). Usage oscillates in individual categories but values are low. Hence, the present intensity of pesticide usage does not threaten the environment, provided that the rules of responsible farming and forestry are followed. Improved funding of enterprises and higher wages may potentially result in a preference for more pesticide-intensive methods and a gradual increase of pesticide consumption, accompanied by associated environmental risks and problems.

The mean annual consumption of pesticides in Slovakia was 3576 tonnes in the past 5 years, of which forestry consumption was 33.6 t, representing a mere 0.94 % of the total usage in spite of the fact that forests cover 41 % of the Slovakia's land area. Expressed as the mean content of active ingredients of pesticides in forestry, it was 8.37 t including 5.7 t of herbicide, 1.012 t of insecticide and 1.654 t of fungicide ingredients (Table 15.7).

In 2006, preventive weed control measures were implemented on the total area of 37 411 ha of young forest (Moravčík *et al.*, 2007). Manual mowing and cutting have been the most common control methods for weeds and undesirable woody vegetation. The use of pesticides is concentrated in forest nurseries, most of which are traditionally considered to be part of the forest. The area of state and privately owned forest nurseries is 682 ha and their net production area 468 ha. The mean nursery area treated by pesticides each year, usually repeatedly, is 444 ha.

Table 15.7 I Pesticide usage on different crops in Slovakia in 2005.

Crop	Total area crop (ha)	% Land area	Area treated (ha)	% Area of each crop treated	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides	1 931 645	41	13 960 [a]	0.73	5.7	0.48
Forestry insecticides/ rodenticides	1 931 645	41	–	–	1.01	0.20
Forestry fungicide	1 931 645	41			1.66	0.09
Total forestry pesticides	**1 931 645**	**41**			**8.37**	**0.77**

[a] New planting/restocking area in 2005; part is untreated, part is treated more than once.

Policy drivers and pesticide regulation

Policy in Slovakia is to minimize pesticide use as far as possible. The European Union's Plant Protection Products Directive reduced the number of pesticides available for forestry applications, and has further encouraged managers to consider alternative chemical and non-chemical solutions to their vegetation management problems.

Regulations on the registration and use of pesticides are governed by EU Directive 91/414/EEC. The relevant Acts incorporated into Slovakia's legal system include:

- Act 193/2005 on Plant Health Care, as amended;
- Act 543/2002 on Nature Protection, as amended;
- Act 364/2004 on Waters.

Data on the use of pesticides are collected by the Central Controlling and Testing Institute in Agriculture (ÚKSÚP) and the National Forest Centre in Slovakia. Users of pesticides provide related data following Article 3 of Act 193/2005 on plant health care and registered traders following Article 21 of the same Act.

The nature conservation act directly affects the use of pesticides. It recognizes 5 degrees of nature protection throughout the whole of Slovakia. As far as pesticides are concerned, terrestrial applications are permitted in almost all areas under degrees of protection 1 and 2. In areas under degree 3 and higher, which include national parks, natural monuments and nature reserves, which cover approximately 25 % of forests, the use of pesticides is subject to the approval of the state environmental authority or is banned.

With respect to policy documents, the draft National Forest Programme is at an advanced stage of public evaluation. The programme aims at law enforcement and also supports forest certification. Although its first draft did not contain a direct reference to the use of chemical agents in forestry, this is likely to be added, together with incentives towards alternative methods.

With regard to forest certification schemes, the area certified under the FSC scheme represents 162 899 ha, and under the PEFC scheme 452 519 ha. Relevant rules of the international FSC standard on the use of pesticides have been pursued, since the draft national FSC standard is still under evaluation. The national PEFC standard does not cover the topic of pesticides directly.

Weed problems

Protection of young forests against weeds is a crucial factor in determining success in artificial forest regeneration. In accordance with the present Forest Act each clearing has to be 'ensured' (fully adapted to environmental conditions including undesirable vegetation) within 10 years from its creation.

Undesirable vegetation significantly increases the mortality of planted and naturally regenerating seedlings and young trees under 10 years of age. Mortality due to weeds is estimated to be 18.3 % in the case of planted seedlings (Varinský, 2002). The negative influence of weeds is greatest within the first 3 years after planting, with conifers proving to be more sensitive to weeds than beech, oaks and other hardwoods. Weeds limit the availability of soil moisture and nutrients for tree seedlings at lower altitudes, and outcompete seedlings in the struggle for light and space at higher elevations.

Major problem weed types impacting on the survival of young naturally regenerating or planted trees are most grass and herbaceous species (*Luzula* sp., *Calamagrostis* sp., *Epilobium* sp., *Solidago* sp., *Senecio* sp., *Petasites* sp. and others), bracken (*Athyrinum filix-femina*, *Dryopteris* sp.), woody species such as raspberry (*Rubus ideus*), bramble (*Rubus hirtus*), and several invasive alien species such as black locust (*Robinia pseudoacacia*), giant hogweed (*Heracleum mantegazzianum*), tree-of-heaven (*Ailanthus altissima*), Japanese knotweed (*Fallopia japonica*), Himalayan balsam (*Impatiens glandulifera*) and Canadian goldenrod (*Solidago canadensis*).

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Slovak forestry

Major weed types and control methods are summarized in Table 5.8.

Silvicultural systems

In accordance with the Forest Act there are two silvicultural systems – shelterwood and selection. Both of them fully exploit natural forest regeneration. The mother stand covers (protects) young trees and is not cut until the next generation has become adapted to environmental conditions and able to survive weed competition. However, these silvicultural systems can be used only in forest regeneration with species suitable for the site.

In addition, there is increasing ratio of clearing due to salvage felling in the total harvest (51.0 % in 2006). Artificial regeneration is required for these areas and dense undesirable vegetation that has negative impact on young seedlings needs to be eliminated (Photo 15.1, page 154). The first stage is to remove the herbaceous layer that has a negative effect mainly within the first five years after reforestation; the next stage involves removal of dense growth of undesirable tree species such as hazel, birch and goat willow.

Mechanical methods

Influenced by terrain conditions, e.g. steep slopes and inexpensive labour costs, manual weed control is the dominating method. Depending on terrain and weed growth intensity, weeds are cleared once or twice per growing season. In recent years, this control has been omitted (or weeds have not been fully cut) owing to extreme summer heat as it is thought that weeds may protect seedlings against heat damage, mostly in cases of beech and silver fir. However, relevant research is required to provide objective information about protection possibilities and competitiveness in root systems.

Mulches

During the 1990s, mulching cloths were used to a minor extent in artificial forest regeneration, mainly in regions affected by acidic pollution. The structure and composition of the mulching cloths aimed to decrease acidity and eliminate weed growth during two or three years after reforestation. However, research did not find sufficiently positive effects. The main problems were inefficient fixing of mulches around seedlings and their high price. There is a need to carry out research on this subject to look at new materials available and to assess cost effectiveness as labour costs increase.

Biological weed control

Herbivorous animals (e.g. cattle and sheep) are not used as a weed control method. There are no plans to exploit insect and fungi for this purpose.

Herbicides

Herbicide use for weed control will probably rise in Slovakia. The main herbicides used in Slovakian woodlands are given in Table 15.9. As an example, Photo 15.2 (page 155) shows the effects of using dichlobenil for protection of young broadleaved trees.

Table 15.8 I Summary of weed types, commonest control methods adopted and impacts in Slovakia's woodlands.

Weed types	Treatment alternatives	Cost (€ ha^{-1})[a]	Effectiveness	Potential environmental impacts
Grasses	Herbicides	106 – 1060	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Mulches	1800 – 2000	Very effective.	Source of chemical waste.
	Cultivation	161 – 1000	Effectiveness varies with weed and site type.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Herbaceous weeds	Cutting	600 – 2000	Only effective on annual species.	Pollution, disruption to ground-nesting birds.
	Herbicides	106 – 800	Very effective.	Poisoning, soil and water pollution, impacts on non- target flora and fauna.
	Mulches	1800 – 2000	Very effective.	Source of chemical waste.
	Cultivation	161 – 1000	Effectiveness varies with site type.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Bracken	Cutting	600 – 2000	Weakens rather than kills.	Pollution, disruption to ground-nesting birds.
	Herbicides	150 – 800	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Cultivation	161 – 1000	Only deep ploughing effective.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Woody weeds	Cutting	353 – 500	Weakens rather than kills; allows herbicides to be used.	Pollution, disruption to ground-nesting birds.
	Herbicides	150 – 1500	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.

[a] Cost for the mean number of 5000 seedlings per hectare and the mean number of treatments 1.5 per year.

Table 15.9 I Main active ingredients of herbicides used in Slovakia's forestry.

Herbicide	kg active ingredient
Forest nurseries	
Glyphosate	805
Hexazinone	583, available until exhaustion of the stock
Dichlobenil	83
Cultures and young growths	
Glyphosate	1317
Hexazinone	1131, available until exhaustion of stock
Dichlobenyl	103
Triclopyr	56

Barriers to adopting alternative methods

While wages are low, the use of pesticides in forestry remains low. Mechanical treatment is the most common method of controlling undesirable vegetation but this situation may change soon following the gradual increase in wages. This fact needs to be reflected in forest-related policies, e.g. with respect to incentives to compensate for higher labour costs in non-pesticide alternatives.

Nursery production appears to be the only forestry activity with high pesticide use. Reduction in the use of pesticides should be possible in nurseries due to technological improvement (better controlled conditions) and promotion of intensive production of potted planted stocks using semi-sterile substrates.

Ongoing research

Attention is being paid to methods through which it is possible to support forest cultures indirectly. The quality of the seedlings and container seedlings used have been issues in artificial forest regeneration during recent years. High quality seedlings adapt better after planting and consequently achieve faster height increment and diameter growth.

Only minimal work has been carried out on the control of difficult invasive alien species in Slovakia.

Future research needs/potential for European collaboration

It is necessary to exploit national and European research results in weed control, especially information and findings on alternative methods such as mulches. This method has not been fully exploited owing to high costs, and new materials and methods need to be researched at a European level. Attention should also be paid to research on invasive herbs and tree species. In Slovakia, there are large areas of forest land within numerous protected areas or water protection zones. Herbicide usage is therefore complicated and results of European research should be obtained and made available.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Ecosystem responses

Current knowledge

Effects of weeds on trees

Herbaceous vegetation, shrubs and mixed pioneer tree species are natural components of forest ecosystems. This vegetative cover is classified as ‘inappropriate vegetation’ or ‘weed’, as it prevents or competes with natural and artificial regeneration of trees. As it is a transient component present in the juvenile successional stage of forest stands, it is therefore desirable to control it only where it prevents natural regeneration of forest tree species, endangers survival or regenerated seedlings, and has an adverse effect on the development of young stands by limiting them in space, availability of light, humidity and nutrients. When the vitality of young trees is suppressed by such competition at an early stage, they become more prone to damage by abiotic factors (frost, droughts, heavy snow) and rodents, more vulnerable to browsing by ungulates and susceptible to diseases.

On the other hand, vegetative cover may have positive effects on target forest tree species. It covers soil and prevents erosion, it can improve microclimate, it is a source of litter, and it can protect tree seedlings against excessive sun and high temperatures.

Research into vegetation management can be classified into both fundamental and applied categories (Eccles *et al.,* 1997). The aim of fundamental research is to obtain primary information about the mechanisms and effects of competitive vegetation on the physiological characteristics of young trees. Knowledge of weed control methods and target weed species is necessary before successful weed control programmes can be developed. These programmes attempt to reduce weed competition to levels which will prevent economic damage to tree crops. Results of these basic studies will inform and enable applied research into the development of methodologies and, subsequently, methods of practical weed control for land vegetation management.

Impact of control methods

Impacts are described in Table 15.8.

Ongoing research

Research within Slovak forestry will continue to focus on weed control treatments, according to their effects on microclimate, in relation to temperature and soil humidity, survival and growth of plants, competition of the rooting systems between plants and weeds during vegetation periods. As far as we know the changes in microclimate and root systems under various vegetation management regimes have neither been published nor explored in Slovakia.

Future research needs/potential for European collaboration

There is a great need to improve knowledge about vegetation management in Slovakia. In particular, information is lacking on interactions between competing herbaceous vegetation and planted trees for available moisture and nutrients, and the way rooting systems compete. The survival of young trees depends also on the morphological and physiological quality of planting stock and its type (bare root, container) and method of planting.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge

Little formal research appears to have been carried out specifically into the social dimensions of vegetation management within woodlands in Slovakia and no future research is planned.

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Spain

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Country background

History

Deforestation has occurred in the Iberian Peninsula since at least the Atlantic Period (7450–4950 BP) and was particularly intensive during the Neolithic, the Roman Period and the Middle Ages. During the 19th century forest expansion in the Iberian Peninsula was at a minimum (Bauer, 1991; González, 1999), and as river heads became deprived of hydrological protection and overflowed, serious and catastrophic flooding events occurred. For this reason, after 1855, most of the remaining mountain woodlands were protected, and forest expansion was increased. As a result of this active policy, important areas were reforested throughout the country up to 1980, either by natural regeneration or by planting. In addition, generalized rural abandonment and a decrease in forest grazing during the second half of the 20th century led to a rapid increase in forested areas which is still ongoing. Estimates indicate that the forest area in Spain has increased from 8 million ha to 16 million ha over the past 150 years (González, 1999). At present the average growing stock is about 2.5 m^3 ha^{-1} yr^{-1} (FAO, 2005).

Up to 1975, hydrological protection and timber production were the most important functions of forests, and forest management focused on these major aims. At present, in the current scenario of low timber prices, a multifunctional approach towards forest management is gaining in importance. Thus, together with the traditional hydrological and productive functions (such as timber and cork production or forest grazing, e.g. 'dehesa' systems), non-productive functions such as biodiversity, landscape and hunting are strong drivers of current management. Intensive production of timber is reduced to a few areas where climate conditions allow the establishment of fast-growing plantations.

Topography and climate

Spain's surface area is 505 955 km^2, occupying around 80 % of the Iberian Peninsula. The average altitude in Spain is 660 m (one of the highest of Europe) and its topography is characterized by a central plateau which occupies 40 % of the country, broken and surrounded by several mountain ranges. The Pyrenees (in the northern part of the peninsula) and the Betic Mountains (in the southern part) are the highest mountain ranges and reach altitudes of over 3000 m.

As a result of this variable topography and the influence of the Atlantic Ocean in the west and the Mediterranean sea in the eastern part of the country, the climate in Spain is very diverse. It can be divided into three different climatic zones: (1) the Atlantic area on the northern coast (with average temperatures of 9 °C and 18 °C in winter and summer, respectively, and annual rainfall between 800–2000 mm); (2) the Continental Mediterranean area of the interior Central Plateau, with cold winters (mean temperatures in January ranging between 3 °C and 5 °C) and warm summers (average 24 °C) and annual rainfall around 500 mm; and (3) the Mediterranean proper area, on the eastern coast, with average temperatures of 11 °C in winter and 23 °C in summer and very variable annual rainfall between 250 mm and 600 mm. In addition there are some regions in which an alpine climate predominates (in the highest mountain ranges) as well as some areas presenting arid (south eastern part of the peninsula) and subtropical climates (Canary Islands).

Woodland area and reforestation policies

Woodlands occupy about 33.4 % of the total land area of Spain which corresponds to about 16.8 million ha (Table 16.1). Agricultural lands occupy a slightly higher proportion of the land area (35.6 %) while pastures and natural meadows occupy more than 7 million ha (14 %). However, as a consequence of rural land abandonment, forested areas are growing very fast at present, at a rate of approximately 367 000 ha yr^{-1} during the period 1995–2005 (González *et al.,* 2006).

Land use	Area (ha)	Percentage (%)
Woodlands	16 867 200	33.4
Agriculture	17 981 100	35.6
Pastures and meadows	7 093 700	14.0
Other	8 594 800	17.0
Total	**50 536 800**	**100**

Table 16.1 | Land use in Spain. Source: Ministerio de Agricultura, Pesca y Alimentación de España (Spanish Ministry of Agriculture, Fish and Food) (2004).

In Spain most woodlands have originated from natural regeneration processes. However around 3.3 million ha were planted between 1938 and 1984 in the context of the national 'Reforestation General Programme' (*Plan General de Repoblaciones;* Peman and Navarro, 1998). Most plantations used conifer species (85 % of the planted area), mainly maritime pine (*Pinus pinaster*: 842 379 ha) and Scots pine (*Pinus sylvestris*: 608 199 ha). Only around 8.3 % of this reforested area was planted by private initiatives. Later, between 1994 and 1999, around 450 000 ha of agricultural lands were reforested in the context of the 'Spanish programme of subsidies to promote forest initiatives in agricultural lands' (based on Council Regulation 2080/92). The mean reforestation cost during this period was around €1350 ha^{-1}. At present, reforestation of agricultural land continues in the context of Council Regulation (EC) 1257/1999 on Support for Rural Development, from the European Agricultural Guidance and Guarantee Fund (EAGGF). These government subsidies, which are regulated by each region, are usually available to cover plantation and management costs for the first years after planting (at a fixed rate which depends on the species being used) with the exemption of fast-growing species plantations (the management practices of which are not subsidized). In addition, owners of reforested agricultural lands can apply for compensatory payments during the first 20 years after planting.

The present annually reforested area in Spain is about 40 000 to 50 000 ha at an average cost of around €2000 ha^{-1} although this figure varies, depending on site conditions and post-planting treatments.

Species composition

Around 35% of woodlands consist of monospecific conifer stands with *P. pinaster* and *P. halepensis* Mill. (Aleppo pine) being the dominant species and occupying, respectively, 1 684 000 and 1 500 000 ha. Monospecific and mixed broadleaf forests make up 34.9 % of woodlands. Most of them are dominated by *Quercus ilex* L. (Holm oak) which is the most prevalent species in Spain and occupies almost 2 million ha (Table 16.2; Photo 16.1). The remaining 30 % are composed of mixed conifer forests.

At present, the main species used in artificial plantations for timber production consist of fast-growing exotic species such as *Pinus radiata* (Monterey pine), *Pseudotsuga menziesii* (Douglas fir) and *Eucalyptus* spp. (eucalyptus). Most of these plantations are localized in the humid Atlantic regions of the Basque country, Asturias and Galicia (northwestern Spain).

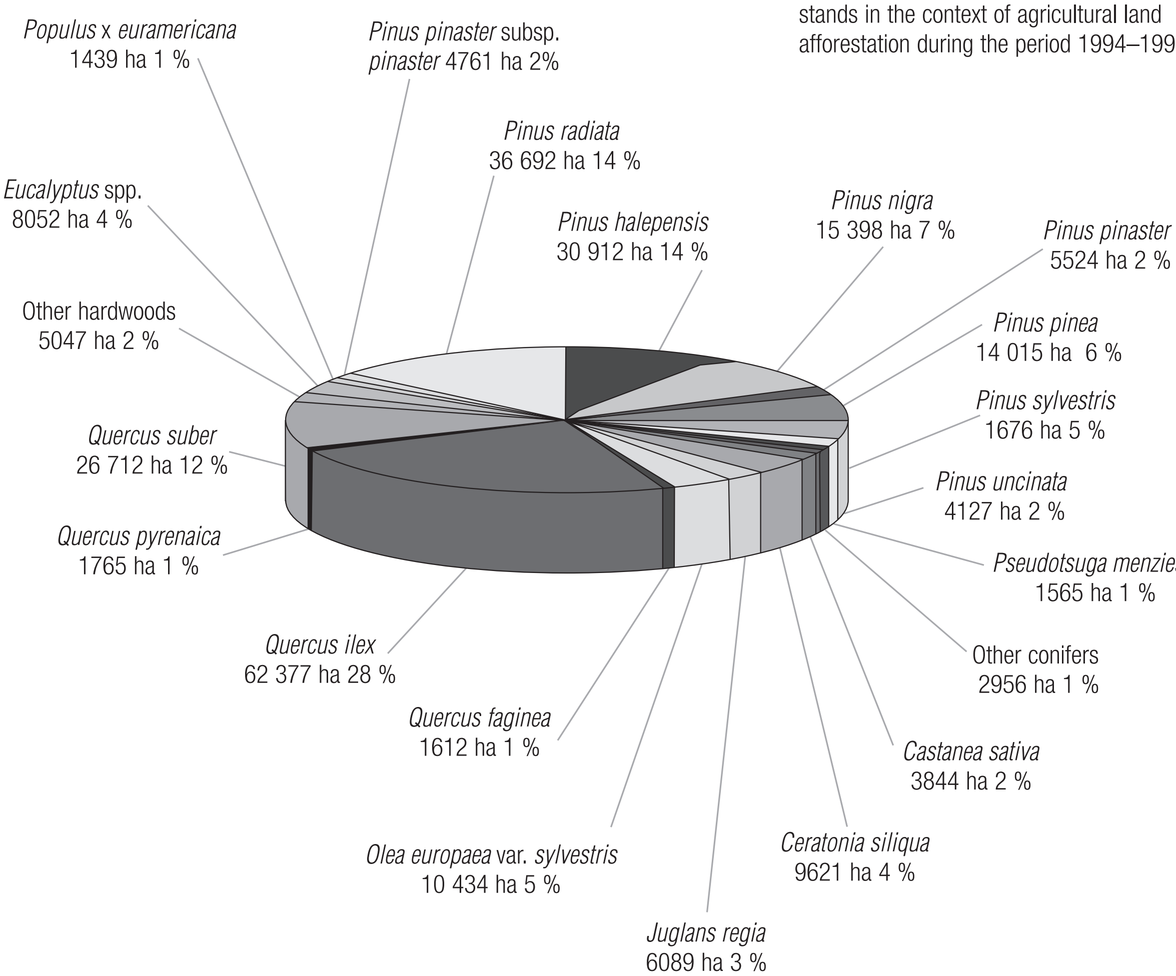
Species	Monospecific (thousand ha)	Mixed (thousand ha)
Quercus ilex Holm oak	1473	503
Pinus pinaster Maritime pine	1058	626
Pinus halepensis Aleppo pine	1365	135
Pinus sylvestris Scots pine	840	370
Pinus nigra Black pine	525	338
Fagus sylvatica Beech	343	105
Quercus pyrenaica Willd / *Q. humilis* Pyrenean oak	313	68
Pinus pinea Stone pine	223	147

Table 16.2 | Main forest species in Spain. Source: DGCN (General Direction of Nature Conservation) (2000).

Afforestation in agricultural lands

At present, herbicide use and vegetation management is particularly relevant in the context of the recent 'Spanish programme of subsidies to promote forest initiatives in agricultural lands' which resulted in about 450 000 ha of afforested agricultural lands between the period 1994–1999 (Ministerio de Agricultura Pesca y Alimentación de España, 2003). This reforestation programme was particularly active in the southern and central regions of Andalucia, Castilla Leon and Castilla La Mancha (with about 66 % of the total national afforested area) followed by the western region of Extremadura and the atlantic regions of Galicia and the Basque country (which represent about the 24 % of the reforested area). In general, monospecific plantations predominate (60 % of the total area), composed mainly of slow-growing broadleaf species (28 %), followed by native conifers (18 %) and non-native fast-growing species (13 %). Mixed plantations constitute 40 % of the afforested areas, with Holm oak and Aleppo pine (*Pinus halepensis*) being the most used mixture (24 000 ha). Figure 16.1 shows the area reforested by each species during the period 1994–1999. Among the broadleaf species, Holm oak (*Quercus ilex*) and cork oak *(Quercus suber)* were the most used species followed by olive (*Olea europaea* (var. *sylvestris*)) and carob tree *(Ceratonia siliqua)*. Authoctonous pines such as *P. halepensis, P. nigra*, *P. pinea* (Photo 16.2, page 155) and *P. sylvestris* predominate among the conifers but exotic *Pinus radiata* has been widely used in the Atlantic provinces (36 692 ha).

Figure 16.1 | Species use in monospecific stands in the context of agricultural land afforestation during the period 1994–1999.



Ownership

Around two-thirds (67%) of Spanish woodlands are privately owned by more than 660 000 forest owners who each have a mean woodland area of about 25 ha. Woodlands classed as 'Montes de Utilidad Pública' (MUP), which could be translated as 'Forests of Public Worth', occupy 3.2 million ha (23.4 % of woodland area) and are mainly owned by municipalities. These are the forests that should be protected or reforested in order to guarantee public health, water regulation, soil fixation and fertility, and their management is under the guidance of the forest administrations. State and communal woodlands represent 6 % and 3.2 %, respectively, of the total woodland area while forests owned by forest industries are fairly scarce. In Spain there are about 1200 protected areas which occupy about 4.65 million ha, and their management basically depends on each region.

Herbicide use and comparisons

Very few herbicides are used in forest management; this is due to the low forest revenue from most woodland which does not compensate for the cost of the main management practices. In addition, the use of herbicides in the forest is generally not included in the forestry practices which receive government subsidies (in contrast to mechanical methods). Herbicide application is therefore restricted to small areas of fast-growing species plantations (e.g. *Pinus radiata, Pseudotsuga menziesii, Eucalyptus globulus, Populus* sp.) in northern Spain, but their use compared to that corresponding to agricultural practices is fairly anecdotal. In contrast, the use of crop protection products in agricultural lands has increased over the past few years (Figure 16.2).

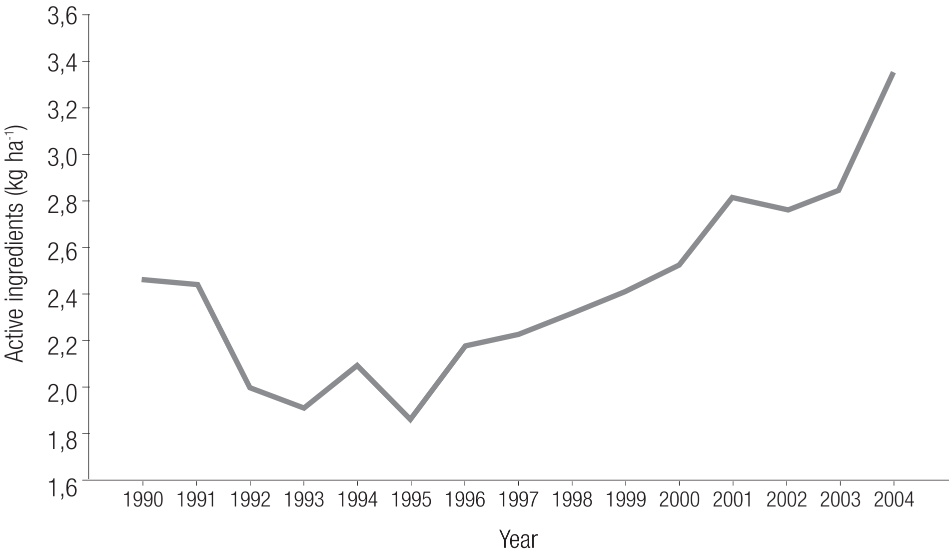


Figure 16.2 I Chemical product use (kg active ingredient/ha^{-1}) in Spain. Source: Spanish Ministry of Agriculture, Fish and Food and Spanish Enterprise Association for Plant Protection (AEPLA).

Herbicides represent about 25 % of the total amount of crop protection products used in Spain (in tonnes of product) while fungicides and insecticides represent 28 % and 18 %, respectively (Table 16.3). Due to the fairly low application of crop protection products in woodlands no specific data are available about their use at national level.

Products	Market (M €)	%	Amount (tonnes)	%
Fungicides	126 522	23.35	27 382	28.42
Herbicides	185 728	34.28	23 985	24.89
Insecticides	126 072	23.27	17 033	17.68
Nematocides	26 325	4.86	11 971	12.42
Fito-regulators	50 625	9.34	9 515	9.87
Molluscicides and rodenticides	6 348	1.17	3 201	3.32
Acaricides	145 148	26.79	692	0.72
Others	5 720	1.06	2 576	2.67
Total	**541 861**	**100**	**96 359**	**100**

Table 16.3 I Crop protection products, market and use in Spain. Source: AEPLA (2005).

Policy drivers and herbicide regulation

The use of herbicides in woodlands is restricted to those registered and approved by the government. Since there has been insufficient research and interest in the topic, the number of authorized products is very low and sometimes their use is restricted to a particular group of species, e.g. conifers, eucalyptus (Navarro and Zaragoza, 2001). Very little regulation exists since, as stated earlier, herbicide application in woodlands is fairly scarce. Therefore, specific policies aimed at reducing herbicide application in forests are not presently a high priority.

About 705 000 ha of Spanish woodlands are certificated at present of which 585 000 ha are approved by the Programme for the Endorsement of Forest Certification (PEFC) and the rest by the Forest Stewardship Council (FSC). Most certificated forests are owned by public institutions (e.g. regional governments) and forest industries. In these forests, as in most protected areas, sustainable forest management standards are implemented and the use of herbicides is only allowed under very specific conditions.

Weed problems

As in many other countries in Europe, bracken *(Pteridum aquilinum)* and bramble *(Rubus fruticosus)* are among the major weeds that create regeneration problems in Spanish woodlands. Their effect is particularly important in the northern part of the country (which does not experience marked drought problems during the growing season) where they have to be periodically removed until forest regeneration reaches a sufficient height above the shrubs. In addition, it is noteworthy to mention the impact of other resprouting species such as tree heath *(Erica arborea)*, sweet chestnut *(Castanea sativa)*, gorse (*Ulex* sp.), box *(Buxus sempervirens)* and strawberry tree *(Arbutus unedo)* which react vigorously to site preparation treatments. In those situations, some local herbicide treatment (manual application at the base of the stool) is practised, although mechanical clearing predominates. As already stated a significant number of agricultural areas have been reforested in Spain during the past decade and weed problems on these areas are particularly important during the first years of establishment. Therefore soil management techniques that limit herbaceous competition but maintain the soil vegetation (in order to reduce soil erosion) are needed (Navarro *et al.*, 2004).

Finally some alien species such as black locust *(Robinia pseudoacacia)* are increasingly proliferating in many open woodlands and can cause serious problems to native species, sometimes requiring specific treatment – usually manual/ mechanical removal or local herbicide application.

Treatments and alternatives

Current knowledge

Methods and strategies adopted for managing weeds in Spanish woodlands

Silvicultural systems

Due to the low revenue associated with most Spanish woodlands, silvicultural and management treatments are usually restricted to those subsidized by public institutions. In general forests are naturally regenerated and no treatment of the competing vegetation is carried out. However, shelterwood or partial cutting predominate over clearfell systems, although the objective of maintaining a certain canopy cover is to protect the seedlings from direct soil exposure (and associated high evaporative demand) rather than to limit the development of soil vegetation.

Clearing

Mechanical clearing is by far the most commonly used method for controlling weeds and shrubs in Spanish forests. Private owners can apply for public subsidies to finance these treatments, the amount and conditions of which depend on each region. The objective of these treatments is generally the reduction of forest fuel loads to reduce fire risk rather than reducing competition. Therefore most clearing operations are localized under high voltage power lines and at the edges of roads and forest tracks.

However, in the fast-growing *Eucalyptus* and *Pinus radiata* plantations of the Atlantic provinces of Spain, clearing treatments are practised during the first 5 years after planting. In the Basque country, for example, foresters can apply for public subsidies (about 30 % of the total cost) to manage the competing vegetation during the first year or the first three years after plantation depending on the species, i.e. eucalyptus or conifers, respectively.

Cultivation

Repeated shallow cultivation is the classical method used for controlling weeds in the context of agricultural land reforestation. However this technique has been proved to be inefficient in many systems since the base of the tree is often left uncultivated (Coll *et al.,* 2007) and can even favour the presence of the most competitive grass species (Boulet-Gercourt, 1999). In addition, high cost makes it unfeasible on a large scale since it demands several interventions per year and can induce erosive problems on particularly wet or muddy sites. The combination of shallow cultivation and herbicide application has been proposed as an appropriate alternative for these sites (Navarro *et al.,* 2004).

Mulches

Sheet mulches are only used on a small scale in Spain. This is mainly due to their high cost which foresters cannot afford when faced with the low productivity and low value of the major part of woodlands and forest products. Inorganic sheet mulches are nevertheless frequently used in higher value agricultural operations such as fruit production.

Biological control – grazing

Understorey grazing by cattle and sheep is increasingly viewed as an efficient, non-expensive method of controlling shrub development in woodlands. This practice is particularly recommended to reduce resprouting after mechanical treatment in areas associated with fire risk. Its use as a method to reduce weed competition for natural resources is less useful since it has to be put in place once the plants reach a certain size (when competition processes are *a priori* less important) (Blazquez *et al.,* 2003, 2005).

Herbicides

As stated above very few herbicides are used in Spanish woodlands. However, use is probably increasing due the need to control herbaceous species in reforestations on agricultural land as well as in fast-growing plantations. Permitted herbicides in forest plantations in Spain are summarized in the Table 16.4. It is difficult to obtain specific data about their usage, but glyphosate is known to be by far the most commonly applied herbicide.

Table 16.4 | Main characteristics of the herbicides authorized for use in forest plantations by the Spanish Ministry of Agriculture, Fish and Food (from Navarro and Zaragoza, 2001).

Herbicide (active ingredient)	Application time	Persistence[a]	Dose (kg active ingredient ha^{-1})	Controlled vegetation
Hexazinone (90%)	Pre-emergence	2–12 months	1–2 (plantations) 2–6 (conifer forest)	Herbs (annuals) and some shrubs
Asulam (40%)	Pre-emergence	3 weeks	1.5–2	Herbs (annuals and some perennials)
Oxyfluorfen (24%)	Pre- and post-emergence	3–6 months	4 (forest) 0.5 (nursery)	Dicotyledenous plants
Glufosinate-ammonium (15–20%)	Post-emergence	Very few residuals (normal conditions)	3–5	Herbs (annuals and perennials)
Glyphosate (36%)	Post-emergence	Very few residuals (normal conditions)	2–4	Herbs (grasses) and some shrubs

[a] Source: AEPLA (2005). Persistence data is established for a non-specific soil under mean environmental conditions

Ongoing research

Very little research has been developed in Spain in the field of forest vegetation management, but interest has been increasing recently, probably due to the implementation of agricultural land reforestation policies which require weed control during the first years after planting in order to succeed (e.g. Navarro *et al.,* 2001). Recent research in forest vegetation management has included:

- The testing of different types of herbicides in conifer plantations (e.g. Peñuelas *et al.,* 1996; Ortega *et al.,* 1999; Villaroya *et al.,* 1999) and hardwood plantations (Jiménez and Cabezuelo, 1995; Jiménez and Saavedra, 1999).
- The comparison of different vegetation management methods (Navarro *et al.,* 2004, 2005).
- The use of shading to control weed development (Rey Benayas *et al.,* 2005).

Future research needs/potential for European collaboration

Future research in Spain may include the use of a combination of shade (tree shelter) and other vegetation management treatments since, under Mediterranean conditions, seedlings need to be protected from high temperatures and summer drought. In addition, the use of cover plants is still anecdotic in Spain and needs to be tested and evaluated in different site conditions. As in other European countries, additional research on the use of alternative herbicides and on different mulch materials is needed, particularly for application in reforestation of ancient agricultural lands. Finally the combination of herbicide application and extensive grazing needs further investigation since it probable represents the best strategy for long-term vegetation management in afforested agricultural lands (Navarro and Zaragoza, 2001; Blázquez *et al.,* 2003, 2005).

Barriers to carrying out future research

At present, research on vegetation management is not among the main priority topics of the different national funding programmes for forestry.

Ecosystem responses

Current knowledge

Effects of weeds on trees

In the humid Atlantic regions of northern Spain competition for light by weeds (mainly bracken and bramble) is important and adequate vegetation management is needed for the success of fast-growing plantations, i.e. *Eucalyptus globulus, Pinus radiata.* In ancient agricultural lands, herbaceous vegetation was controlled to allow the establishment of the introduced plants since herbs exert serious competition for below-ground resources during the first years after planting, compromising growth and survival.

Nature and magnitudes of effects

Competition seems to be particularly important on the best sites which are characterized by rich soils without marked periods of drought. In contrast, positive interactions between species seem to predominate in less productive environments such as in infertile semi-arid lands (e.g. Pugnaire and Luque, 2001).

Ongoing research

Research in Spain on the analysis of how plant interactions vary depending on the severity of the environment has been ongoing for several years. The use of vegetation (and particularly shrubs) as nurse plants in the restoration of degraded areas is also being studied in different types of environments (for example see Castro *et al.,* 2002; Maestre *et al.,* 2001; Gomez-Aparicio *et al.,* 2004; Gasque and García-Fayos, 2004).

Other relevant research topics include the study of the response of plants and the ecosystem to different soil conservation techniques (including livestock use) in agroforestry, particularly silvopastoral systems.

Future research needs/potential for European collaboration

Requirements for future research in Spain include improving the understanding of the dynamics of invasive species such as *Robinia pseudoacacia* or *Ailanthus altissima* as well as developing models to assess the effect of climate change on invasive ecology. Improving the understanding of the competitive effect of different weed types as well as assessing the ability of different species of trees to tolerate competition is also relevant for the reforestation of agricultural land. Determining the relationship between the overstorey canopy cover and both the understorey development and natural regeneration for different forest types would be of interest in order to design adequate forest management plans which reduce fire risk and competition following regeneration cuts.

Barriers to carrying out future research

At present very little funding exists for research in forest vegetation management due to the low revenue associated with most Spanish woodlands.

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17 Sweden

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Country background

History

Protection of the timber resource in Sweden has a long history. Since the 16th century oak trees, which the navy depended upon, have been protected in various ways. In the middle of the 19th century agricultural land was at its most widespread but forests have always dominated the landscape in Sweden compared with other European countries. Only in a few regions in southern Sweden were large areas converted into agriculture. At the beginning of the 20th century, a law was introduced that required regeneration following clearfelling. Since the 1940s, successive governments have encouraged landowners to create new forests, and to maximize the productivity of existing forests through intensive techniques such as using conifer tree species, fertilization, mechanical site preparation, ditching, improved planting material and use of pesticides.

Annual growth in the productive forests today is 106 million cubic metres (m^3) (Anon., 2006a). In 1920, it was 60 million m^3 annually. The largest increase has taken place in southern Sweden. During the same period, the standing volume has increased by 60 %. However, since 1993 the emphasis has shifted more towards multiple purpose forestry, giving environmental goals and conservation of biodiversity the same importance in the forestry act as sustainable timber yield (Anon., 1992). During recent years the social values of the forests have also come into focus (Anon., 2006b).

Topography and climate

The topography of Sweden is highly variable, from rounded arctic mountains in the northwest to flat forested areas including large numbers of small lakes, swamps and rivers to the northeast and south. Mean annual temperatures in January and July are –8 °C (0 to –17 °C) and 12 °C (17 to 7 °C), respectively. Mean annual precipitation is between 500 and 1100 mm, with much more precipitation in the southwest coastal areas and in some arctic mountains. Mean number of growing degree-days (> 5 °C) is 165 but varies greatly from the north (130) to the south (200).

Woodland area

Productive forests, i.e. those with timber production of more than 1 cubic metre per hectare per year (m^3 ha^{-1} yr^{-1}), occupy 22.9 million ha or 55.8 % of the land area of Sweden (Table 17.1). In addition, small areas of mountain forests, exceeding the production criterion, are excluded from the this figure. Except for those mountain forests, little other virgin or natural forest remains. Less than 2 % of the productive forest area is protected from economic forestry (Table 17.2). This figure includes national parks, various kinds of reserves and forests protected on a voluntary basis. Many of the protected forests are old-growth forests that have been continuously forested over a long period of time. The remaining 82.5 % of the forested area comprises secondary and plantation forests (Table 17.2).

Land use	Area (ha)	Percentage (%)
Productive forests	22 900 000	55.8
Mountains and mountain forests	4 300 000	10.5
Swamps	4 500 000	11.0
Agriculture	3 400 000	8.3
Urban	960 000	2.3
Other	4 940 000	12.0
Total	**41 000 000**	**100**

Table 17.1 | Land use in Sweden. Source: *Swedish statistical yearbook of forestry* (Anon., 2006a).

Forest type	Area (ha)	Percentage (%)
Mountains and mountain forests	4 300 000	15.8
Protected forests	460 000	1.7
Secondary and plantation forests	22 440 000	82.5

Table 17.2 | Natural and plantation forests in Sweden. *Source: Swedish statistical yearbook of forestry* (Anon., 2006a).

Species composition and productivity

Productive forests in Sweden have a total standing volume of 3.1 billion m^3. These forests are dominated by coniferous tree species such as native Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) which make up 39 % and 42 % of the standing volume, respectively. Native birch (*Betula*) spp. make up 11 % of the standing volume and other broadleaves only approximately 6 %. Boreal coniferous forest is the dominant forest type. Mean productivity of the country growing stock is 5.3 m^3 ha^{-1} yr^{-1}. Productivity is low in the northern part of the country and increases gradually when moving southwards. In the southernmost part of Sweden, which belongs to the temperate broadleaved forest region, a higher diversity of native tree species is present including more broadleaved trees. Exotic species, mainly lodgepole pine (*Pinus contorta*) and larch (*Larix* spp.), have been planted to a limited extent.

Ownership and subsidy regime

Of the productive forests, around 51 % are individually-owned, relatively small private forests. Approximately 30 % is owned by other private forest owners and larger forest companies or industries, and the remaining 19 % by the state. About 67 % of all annual reforestations (227 000 ha) are regenerated by planting or sowing, at a cost of approximately €600–€2000 ha^{-1}, but at some temperate broadleaved sites the cost for regeneration may be as high as €6500 ha^{-1}. About one-third of reforestation is achieved through natural regenerations, mostly of *Pinus sylvestris*. The costs are similar (€600–€2000 ha^{-1}) to artificial regeneration due to the use of mechanical site preparation and treatment of shelterwood trees. Various forms of government regulations and laws influence forest management. Minimum standards of nature protection has to be implemented in all productive forests, e.g. high stumps, green tree retention and borders along streams and lakes. Forest owners have a duty to report final fellings to government. A minimum number of seedlings is required by five years after final felling at most sites. At some sites in harsh climates the time limit is expanded to ten years. Government subsidies are usually not available for regeneration measures but exceptions such as regeneration following storm events and afforestation campaigns can be government funded. Another exception is the regeneration of valuable native broadleaves including Norway maple (*Acer platanoides*), hornbeam (*Carpinus betulus*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), wild cherry (*Prunus avium*), pedunculate oak (*Quercus robur*), lime (*Tilia cordata*) and wych elm (*Ulmus glabra*). Here, 80 % of the regeneration costs may be covered by government grants.

Silvicultural systems

High-forest clearfelling in pure even-aged stands followed by planting is the main silvicultural system in Sweden, and operations are heavily mechanized (Karlsson and Lönnstedt, 2006). Natural regeneration of *Pinus sylvestris* stands using uniform shelterwood systems is also common (Photo 17.1, page 156). Alternative silvicultural approaches such as continuous cover forestry or nature-based silviculture (Larsen and Nielsen, 2007) are much debated but not put into practice, except in some urban forests and nature reserves.

Herbicide use and comparisons

Almost no herbicides are used today in Swedish forestry (Table 17.3). By contrast, substantial amounts are used when cultivating crops other than trees. However, herbicides were commonly used in forestry from approximately 1950 until 1980. The introduction of large clearcuts improved conditions for naturally regenerated *Betula* spp. and aspen (*Populus tremula*) which negatively affected the growth of planted *Pinus sylvestris* and *Picea abies*. To control the 'weed-tree species' herbicides were spread manually or from the air. Environmental concern and health issues led to regulations (Anon., 1997; Anon., 1998). Today herbicides may only be used on forest land following strict governmental control, and they are rarely applied. Instead mechanical site preparation and manual pre-commercial thinning is used to facilitate planting, improve planting spots and control competing natural vegetation (see Treatments and alternatives, page 143).

Crop	Total area crop (ha)	% Land area	Area treated (ha)	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides	22 900 000	55.8	n/a	0.1	0.005
Forestry insecticides and deterrents	22 900 000	55.8	n/a	3.8	8.5
Forestry fungicides	22 900 000	55.8	n/a	1	0.4
Total forestry pesticides	**22 900 000**	**55.8**	**n/a**	**4.9**	**0.2**
Agricultural pesticides	3 400 000	8.3	n/a	1279.5	71.5
Horticultural pesticides	n/a	n/a	n/a	58	3.2
Industrial pesticides	n/a	n/a	n/a	0.8	0.04
Household pesticides	n/a	n/a	n/a	451.2	25.2

n/a: data not available.

Table 17.3 I Pesticide usage in forestry and on different crops in Sweden. Information based on quantities of pesticides sold in Sweden in 2005 (Anon., 2006c).

Policy drivers and pesticide regulation

Swedish Government and European Union policy is to minimize pesticide use as far as possible. As noted above, almost no herbicides are being used in forestry. Other pesticides used in forestry have also decreased during recent years (Anon., 2006c; Photo 17.2, page 156).

Weed problems

Grass and herbaceous vegetation interfere with planted and naturally regenerated seedlings in all parts of Sweden. In the north various grasses, such as wavy hairgrass (*Deschampsia flexuosa*), reduce growth and survival in seedlings. Allelopathic species such as *Empetrum hermaphroditum* may also limit seed germination and establishment of some tree species. In the south and at more fertile sites, competition from grass and herbaceous vegetation on seedlings is stronger. However, because of high browsing pressure from roe deer on herbaceous vegetation, clearcut sites are also often dominated by grasses such as *D. flexuosa* in the south (Bergquist *et al.,* 1999). Interference from woody vegetation such as *Betula* spp. and *Populus tremula* also occurs all over the country since natural regeneration of these species is often promoted by clearcutting.

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in Swedish forests

Methods and strategies for weed management are summarized in Table 17.4.

Silvicultural systems

Natural regeneration of *Pinus sylvestris* stands using uniform shelterwood systems generally reduces interference from grass and herbaceous species. This method is put into practice in most parts of Sweden. However, on fertile sites, natural regeneration often fails due to competition from ground vegetation (Nilsson *et al.,* 2006). Other alternative silvicultural approaches with the potential to reduce competition from ground vegetation, such as continuous cover forestry with *Picea abies* and *Fagus sylvatica*, are of little importance in practical forestry in Sweden.

Motor-manual methods

Manual pre-commercial thinning using a brushsaw is used to control natural woody vegetation that interferes with planted or naturally regenerated seedlings all over the country. Around 370 000 ha per year are treated in this way (Anon., 2006a). Often, pre-commercial thinning is done twice: one treatment when the planted seedlings are below 1 m high and a second treatment when the regeneration has reached about 3 m. On more fertile, valuable, broadleaved forest sites in the southernmost parts of Sweden, grass and herbaceous species may be cut manually using a brushsaw during the first years after planting. This costly method is favoured since governmental grants may cover up to 80 % of the regeneration costs.

Mechanical site preparation

Mechanical soil cultivation such as scarification or mounding is standard procedure on most regeneration sites in Sweden. Disk trenching accounts for almost half of the treated area and the second most common treatments are mounding or patch scarification. Mounding is a more intensive method that improves tree establishment on sites where the groundwater table is close to the soil surface and also alleviates growth restrictions due to soil compaction (Örlander *et al.*, 1998).

Annually, approximately 170 000 ha are treated by mechanical site preparation in Sweden (Anon., 2006a). It reduces interference from grass and herbaceous vegetation especially during the first two years following planting or natural regeneration (Nilsson and Örlander, 1999). However, on more fertile sites in southern Sweden the positive effect is weaker. Other positive effects are that scarification increases soil temperature and offers protection of seedlings from damage by pine weevils *(Hylobius abietis)* (Örlander and Nilsson, 1998).

Mulches

Sheet mulches of various materials and bark and other organic mulches are used on a very small scale in Sweden. Although mulching can be an effective alternative to herbicide treatment it is generally considered expensive and the mulches are sometimes difficult to handle. They are mainly used in urban and roadside plantings.

Biological weed control

Biological methods such as host-specific natural enemies, i.e. arthropods and diseases, have not been used for weed control on forest land in Sweden.

Prescribed burning

Prescribed burning in stands dominated by *Pinus sylvestris* is used as an alternative method for vegetation control following clearcutting. According to certification rules a certain area has to be treated with prescribed burning, but the areas treated are small and the method is looked upon as a restoration practice to restore natural disturbance regimes.

Herbicides

Herbicides are not used as a method of vegetation management on existing forest land in Sweden. Permission may be obtained in exceptional cases. However, herbicide application is quite common in connection with afforestation of abandoned farmland, especially if heavy root competition is anticipated.

Table 17.4 | Summary of weed types, commonest control methods adopted and impacts in Swedish forests.

Weed types	Treatment alternatives	Cost (€ ha^{-1})[a]	Effectiveness	Potential environmental impacts
Grasses and herbaceous weeds	Mechanical site preparation	150–500	Effectiveness varies with site type and intensity	Nutrient leaching, damage to buried archaeological remains
	Prescribed burning	500–1000	Effectiveness varies with site type and intensity	Problems with smoke, risk of spreading of fire
	Motor-manual methods	300–500	Weakens rather than kills; often requires repeated treatments	Disruption of ground-nesting birds and other fauna
Competing woody vegetation	Motor-manual methods	200–600	Effective; repeated treatments sometimes required	Disruption of ground-nesting birds and other fauna, and reduced tree diversity

[a] Costs depend on the intensity of treatments and if treatments are repeated. Mounding for example is more costly than soil scarification and motor-manual pre-commercial thinning may be repeated at some sites.

Ongoing research

Current forest research includes:

1. Development of inverted mechanical site preparation which is similar to, and has the same advantages as, mounding site preparation but does not create elevated mounds and reduces the disturbed area (Örlander *et al.,* 1998; Hallsby and Örlander, 2004). Development of this method also includes work on new machinery. Further evaluations of other mechanical site preparation methods and their effect on seedling growth and survival are also ongoing (Nordborg, 2001).
2. Development of silvicultural systems for reduced interference from ground vegetation. This includes testing various nurse crops and shelterwood densities (Löf *et al.,* 2004; Löf *et al.,* 2005).
3. To reduce costs in motor-manual pre-commercial thinning, research is focusing on (a) alternative ways of cutting competitive tree species, for example top-cutting instead of cutting near the ground (Karlsson and Albrektsson, 2001), and (b) improving the timing of pre-commercial thinning in conifer plantations. The development of machinery for mechanization of this work is also under way.

In the agricultural and horticultural sectors some research has started on biological weed control methods. Research on thermal methods (steam, hot water and flames) has also been ongoing (Norberg *et al.,* 1997).

Future research needs/potential for European collaboration

Examples of requirements for future forest research in Sweden, that may be amenable to European collaboration, include the further development of mechanical site preparation methods and pre-commercial thinning, the use of cover plants, alternative biological control methods and the use of alternative silvicultural methods for vegetation control.

Barriers to carrying out future research

Most research on forest vegetation management in Sweden is based on methods adapted to boreal forest conditions. Therefore, collaboration with Finland and Canada, for example, is common, but not with the rest of Europe. Different kinds of vegetation zones and climate may be a barrier for future research.

Ecosystem responses

Current knowledge

Effects of weeds on trees

One important aspect in Sweden is that recolonization of grass and herbaceous species in scarified areas improves conditions for the large pine weevil (*Hylobius abietis*) that debarks young coniferous seedlings (Petersson, 2004). Mechanical soil preparation may decrease such damage by creating bare soil (Petersson, 2004). The pine weevil is not a serious problem for broadleaved tree seedlings (Löf *et al.,* 2004) but other destructive agents such as voles may be the cause of low survival in broadleaf regeneration when abundant ground vegetation is present (Löf *et al.,* 2006). Competition from ground vegetation can be strong during dry years and on fertile sites (Nilsson and Örlander, 1995; Löf, 2000); this is mainly below ground for soil water and nutrients (Nilsson and Örlander, 1999). In young stands with fast growing woody competitors, competition for light is more severe (Karlsson and Albrektsson, 2001). Allelopathy from *Empetrum hermaphroditum*, for example, has been shown to be a factor controlling regeneration of some tree species in northern Sweden (Nilsson, 1992).

Nature and magnitudes of effects

The costs of pine weevil damage to Swedish forestry have been estimated at several million euros annually (Thuresson *et al.,* 2003). Weed control that improves seedling growth helps seedlings to grow out of the vulnerable stage faster and therefore reduces the negative impacts of pine weevil damage as well as browsing damage by roe deer. The cost of damage by voles in broadleaved plantations with abundant ground vegetation may also be high; but nationally this damage is of little importance as only small areas are planted with broadleaves. Below-ground competition may cause low growth in seedlings, an effect that increases when more fertile sites are planted (Löf, 2000). However, the long-term effect of competition from ground vegetation on seedlings is small (Nilsson and Örlander, 1999). Competition from woody vegetation in young stands has also been estimated to result in high annual costs to forestry due to damage and lost production.

Ongoing research

Research on the relative competitiveness of different ground vegetation species (bushes, grass and herbaceous) and the relative importance of below- and above-ground competition is ongoing at the Swedish University of Agricultural Science. Research is also in progress on the allelopathic effects from different herbaceous species on tree seedling establishment.

Future research needs/potential for European collaboration

Some examples of requirements for future research in Sweden, that may be amenable to European collaboration, include:

- Developing a greater understanding of the biology, ecology and competitive effects of grass and herbaceous species under current and future climate change scenarios.
- Deriving an improved understanding of the competitive relationships between different species of trees and weeds.
- Developing models to predict the response of weeds and tree seedlings to different silvicultural treatments on different sites in order to aid decision making and forest management planning.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge and future research needs

Little formal research appears to have been carried out specifically into the social dimensions of vegetation management within forests in Sweden. There is a need for research into attitudes and perceptions of risk for forest vegetation management practices and possible alternatives.

Barriers to carrying out future research

The main barrier is lack of funding. There are probably researchers in Sweden interested in participating in such investigations if funding could be secured.

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18 United Kingdom

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Country background

History

The history of woodland in the British Isles begins around 11 000 BC, when the ice sheets covering much of the land surface retreated, and we entered our current, warmer, interglacial period. Waves of colonization of different tree species spread over the prevailing tundra and moorland from the south. By the time the land bridge to the European continent was cut off by rising sea levels in around 8500 BC, ancient wildwood covered most of Britain and its composition was relatively stable. In different areas of the country climax woodlands may have been dominated by lime (*Tilia cordata*), beech (*Fagus sylvatica*), Scots pine (*Pinus sylvestris*), oak (*Quercus petraea, Q. robur*), hazel (*Corylus avellana*) or birch (*Betula pendula, B. pubescens*), but woodlands were heterogeneous, with species such as ash (*Fraxinus excelsior*), elm (*Ulmus* sp.) and alder (*Alnus glutinosa*) being important locally (Rackham, 1990). With the arrival of man after 4500 BC, the native wildwood was successively cleared and the remnants intensively managed, until by the turn of the 20th century less than 5 % of the United Kingdom (UK) was covered in forests.

Since the 1920s, successive governments have encouraged landowners to create new woodlands, and to maximize the productivity of existing forests, through intensive techniques such as coniferization, fertilization, site cultivation, improved planting stock and the use of pesticides. Although these policies were successful in increasing forest cover to over 11 % of the land area of the UK, the primary focus on timber production increasingly came into question. Since the early 1990s there has been a shift in emphasis away from the objective of establishing a strategic reserve of timber towards providing multiple use woodlands and the protection of those semi-natural woodlands that remain (Forestry Commission, 2004). This trend has been accelerated in recent years with a reduction in timber prices, causing intangible, non-market benefits to become increasingly important. Most woodland management in the UK now includes one or more of the following major aims: to promote and conserve biological diversity; to improve the landscape; to provide a recreational resource; to produce timber and hence encourage rural development.

Topgraphy and climate

The UK is an island nation separated from its neighbouring countries by the English Channel, the Irish Sea and the North Sea. Much of the coastline is rugged and indented with cliffs and bays, river estuaries and harbours. Altitude ranges from over 1300 m in the mountainous Scottish Highlands in the north to sea level in the low lying, east coast English Fens. Several large and deep lakes are found in Northern Ireland and the Scottish Highlands. England comprises the hill and moorland regions of the north, and the rolling downs and low plains of the east and southeast, including rich, fertile agricultural lands. Scotland's landscape is highly varied including the Highlands in the north, valleys and moorlands. Wales is largely mountainous and pasture, while Northern Ireland has a mix of mountains, hills and plateaus.

The UK has a maritime climate, with conditions generally being cooler in the north of the country compared to the south, and wetter in the west compared to the east. Average annual precipitation ranges from 505 to 4130 mm (average of 1060 mm), being greatest in the more mountainous regions in the north and west of the country. Mean January (winter) temperature ranges from –2.5 to 7.8 °C (average of 3.1 °C), and mean July (summer) temperature ranges from 6.9 to 18.0 °C (average of 14.4 °C), giving a mean annual average temperature of 8.4 °C. Growing season length is in the range 90–361 days (average 276 days), with 148–2415 (average 1415) annual growing degree-days (> 4 °C).

Woodland area

Woodlands occupy 2.8 million hectares, or 11.6 % of the land area of the UK, but no undisturbed natural forests remain (Table 18.1). Less than 1 % of the land area (0.4 % of the forest area) is occupied by 'ancient semi-natural woodlands', which are defined as sites which have been continuously wooded since 1600 AD and, although managed, still comprise predominantly native trees that have not been planted. The remaining 99 % of the forest area comprises secondary and plantation woodland (Table 18.2). Around 24 000 ha are regenerated or afforested annually, at a cost of approximately €2800–€6000 ha^{-1}, excluding the cost of any land purchase.

Land use	Area (ha)	Percentage (%)
Forests	2 825 000	11.6
Agriculture	17 967 000	74.0
Urban/other	3 499 000	14.0
Total	**24 291 000**	**100**

Table 18.1 I Land use in the United Kingdom. Source: Defra (2005).

Forest type	Area (ha)	Percentage (%)
Virgin natural forest	0	0.0
ASNW [a]	11 400	0.4
PAWS [b]	181 000	6.4
Secondary and plantation woodland	2 632 600	93.2

[a] ASNW: ancient semi-natural woodland, defined as sites which have been continuously wooded since 1600 AD, and although managed, still comprise predominantly native species that have not been planted.
[b] PAWS: plantations on ancient woodland sites; ancient in the sense of being continuously wooded since 1600 AD, but not semi-natural.

Table 18.2 I Natural and plantation woodland in the United Kingdom. Source: Forestry Commission (2005).

Species composition

Of the secondary woodland, 58 % consists of mainly introduced exotic coniferous species such as Sitka spruce (*Picea sitchensis*), Norway spruce (*Picea abies*), Douglas-fir (*Pseudotsuga menziesii*), pines (*Pinus* spp.) and larches (*Larix* spp.) grown in plantations. The balance comprises woodlands of conifers and/or predominantly native broadleaves such as oak (*Quercus robur, Q. petraea*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), birch (*Betula pendula, B. pubescens*) and cherry (*Prunus avium*).

Ownership and subsidy regime

Around 30 % of woodlands are publicly owned, and approximately 25 000 ha are planted or restocked annually. Various degrees of statutory protection exist that affect woodland management, and government licensing is required for almost all tree felling (Table 18.3). Government grants are usually available to cover between 20 and 90 % of regeneration costs, depending on location and objective.

Type of protection	Area (ha)	Percentage (%) of total woodland area
Statutory protection [a]	180 000	6.4
Protective ownership [b]	1 868 000	66.1
Forest certification [c]	1 492 000	52.8
Felling licence required [d]	2 825 000	100

[a] Forests with the highest level of legal protection due to their conservation value.
[b] Forests under some form of protective ownership, either publicly owned, or privately owned but receiving government grants requiring particular forms of protective management.
[c] Forests certified under the UK Woodland Assurance Scheme, ratified by the Forest Stewardship Council (1 489 000 ha) and the PEFC (2500 ha) (FSC, 2006).
[d] Forests requiring licences to be issued by the UK government before felling can take place. Restocking is usually a condition of granting the licence. Generally, all felling requires a licence, although there are some exceptions, such as routine thinning operations.

Table 18.3 I Protected woodland areas in the United Kingdom. Source: Forestry Commission (2005).

Silvicultural systems

Clearfell and replant systems predominate, but alternative silvicultural approaches using natural regeneration, such as continuous cover forestry (Mason *et al.,* 1999) are becoming increasingly important in the UK (see Silvicultural systems in Treatments and alternatives section, page 148).

Herbicide use and comparisons

One result of a shift in the objectives for woodland management has been a reduction in the resources owners are prepared to invest in operations such as vegetation management. The use of herbicides is easily the most cost-effective method of weed control in the UK, but, even so, economic pressures have encouraged managers to limit spraying only to areas where it is necessary to allow establishment of trees. Such economic pressures and changing objectives have therefore already led to some reduction in herbicide use in UK forestry. Total annual herbicide use in British forestry has been estimated at 32 tonnes of active ingredient, approximately 0.1 % of the total pesticide used in Britain, despite woodlands making up more than 11 % of the land area of the country (Table 18.4).

Table 18.4 | Estimated pesticide usage on different crops in Britain.

Crop	Total crop area (ha)	% Land area	Area treated (ha)	% Area of each crop treated	Tonnes active ingredient used	% Total active ingredient used
Forestry herbicides	2 406 000	11	34 000 [b]	1.4	32	0.1
Forestry insecticides/ rodenticides	2 406 000	11	–	–	2	–
Forestry urea (fungicide)	2 406 000	11	16 400 [c]	0.7	480 [d]	1.4
Total forestry pesticides	**2 406 000**	**11**	**50 400**	**2.1**	**514 [e]**	**1.5**
Arable	4 563 920	20	42 444 236	930 [f, g]	28 746	84
Glasshouse	4 050	0.02	58 657	1 448 [f, g]	148	0.4
Grassland	10 490 279	47	2 275 359	21 [f, g]	1 744	5.1
Nurseries	8 172	0.04	62 827	768 [f, g]	108	0.3
Fruit	4 044	0.02	832 012	2 000 [f, g]	691	2
Vegetables	15 256	0.7	1 053 705	690 [f, g]	903	2.7
Other agricultural	9 831	0.04	178 094	1 800 [f, g]	721	2.1
Industrial and non-crop	4 598 000	20.6	n/a	n/a	633	2

[a] Crop area figures exclude Northern Ireland, and were collected before 2005, hence total land area differs slightly from the value given in Table 18.1.
[b] Estimate based on total annual new planting/restocking area; part will be untreated, but part will be treated more than once.
[c] Restock area treated with urea and pesticides after planting.
[d] Urea is a commodity substance – a fertilizer used as a cut stump treatment.
[e] Estimated total forestry usage, based upon state forests as 35 % of total.
[f] Some areas treated more than once.
[g] Agricultural and industrial figures produced by Central Science Laboratory Pesticide Usage Survey (Defra) in 1990s; actual pesticide use is likely to have declined since data was collected.
AI: active ingredient; n/a: data not available.

Policy drivers and pesticide regulation

UK Government and European Union policy is to minimize pesticide use as far as possible. Statutory codes of practice (Defra, 2006) oblige managers to consider whether, in any given situation, pesticide use is really necessary and, if possible, to adopt either wholly non-chemical methods, or techniques based on reduced quantities of chemicals used as part of an integrated approach to crop management. The European Union Plant Protection Products Directive has resulted in a reduction in the number of pesticides available for use in forests, and has further encouraged managers to consider alternative chemical and non-chemical solutions to their vegetation management problems.

Approximately 53 % of UK woodlands (Table 18.3) are managed under the terms of a voluntary certification initiative, the United Kingdom Woodland Assurance Standard (UKWAS, 2006), which is approved by both the Forest Stewardship Council and the Programme for the Endorsement of Forest Certification schemes (PEFC). UKWAS gives standards for sustainable forest management against which management units can be assessed. It also calls for managers to develop a strategy which will lead to a reduction, and eventually an elimination, of all synthetic pesticide use. Where there is no practical alternative not entailing excessive cost, the use of synthetic pesticides is still permitted.

Weed problems

The major problem weed types impacting on the survival of young naturally regenerating or planted trees include most grass and herbaceous species, bracken (*Pteridium aquilinum*), woody species such as bramble (*Rubus fruticosus* agg.), heather (*Calluna vulgaris*) and gorse (*Ulex europaeus*), and invasive alien species such as Japanese knotweed (*Fallopia japonica*) and rhododendron (*Rhododendron ponticum*, Photo 18.1, page 156; Edwards, 2006). Where competitive species co-exist with young trees, some form of vegetation management is usually required irrespective of woodland type or of the silvicultural practice adopted. However, silvicultural systems which avoid clearfelling can in some cases reduce the need for direct interventions, and particular care may need to be taken to reduce the risk of adverse impacts from weeding in ancient semi-natural woodlands and other protected areas. Location and specific site and soil characteristics have the greatest influence on the presence and vigour of any particular weed species. In very general terms, heavier textured soils and those sites located at lower altitude in the warmer, drier and more fertile locations in the southern half of Britain are particularly problematic for weed competition.

Treatments and alternatives

Current knowledge

Methods/strategies adopted for managing weeds in British woodlands

Methods and strategies for managing weeds are summarized in Table 18.5.

Silvicultural systems

Alternative silvicultural approaches to the management of woodlands such as continuous cover forestry (Mason *et al.,* 1999) and restoration to native species of conifer plantations on ancient woodland sites (Thompson *et al.,* 2003) partly reflect changing objectives for woodland management. However, there is also the perception among some managers that these systems will offer a lower cost approach that may require less intensive inputs than more prevalent clearfell and replant systems. However, in reality, such approaches may still require the use of herbicides in the transformation phase and beyond, particularly with light demanding tree species on more fertile sites, and with invasive and alien weed species.

Mechanical methods

With the high cost of labour, manual techniques such as pulling of weeds are largely impractical. However, cutting by machine or hand tools is sometimes used to assist later herbicide application, particularly with tall growing herbaceous and woody weed species.

Cultivation

Cultivation is extensively practised to relieve soil compaction and assist in tree establishment (Photo 18.2, page 156). Its effectiveness for weed control varies with site and locations. On less fertile sites in conifer plantations in the upland (>250 m altitude) north and west of Britain, cultivation before planting may give up to 2–3 years' worth of weed suppression, sufficient to establish trees with no requirement for further vegetation management. However, on more fertile lowland sites cultivation can actually make weed problems worse.

Mulches

Inorganic plastic sheet mulches are used on a small scale in Britain, and can be effective alternatives to herbicides. However, they are expensive, can be difficult to fix and maintain, and unless collected at the end of their useful life can form a source of chemical waste. Bark and other organic mulches are used extensively in landscape and roadside plantings, but are usually impractical, ineffective and excessively costly in woodland settings. Biodegradable sheet mulches are generally not currently used.

Biological weed control

While grazing animals such as cattle, sheep and pigs are sometimes used locally to control weeds, to date host-specific natural enemies, i.e. arthropods (in particular insects and mites) and diseases (in particular fungal pathogens), have not been exploited for the biological control of invasive alien weeds in Britain in Europe.

Herbicides

Herbicides are the most commonly used method of vegetation management. The main herbicides used in British woodlands, along with an estimate of annual usage, are given in Table 18.6.

Table 18.5 I Summary of weed types, common control methods adopted and their potential impacts in British woodlands.

Weed types	Treatment alternatives	Cost (€ ha^{-1})[a]	Effectiveness	Potential environmental impacts
Grasses	Herbicides	70–1500	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Mulches	5500–16 800	Very effective.	Source of chemical waste.
	Cultivation	150–600	Effectiveness varies with weed and site type.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Herbaceous weeds	Cutting	600–2000	Only effective on annual species.	Pollution, disruption to ground-nesting birds.
	Herbicides	70–1500	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Mulches	5500–168 000	Very effective.	Source of chemical waste.
	Cultivation	150–600	Effectiveness varies with site type.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Bracken	Cutting	600–2000	Weakens rather than kills.	Pollution, disruption to ground-nesting birds
	Herbicides	150–1500	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
	Cultivation	150–600	Only deep ploughing is effective.	Soil erosion, water sedimentation, pollution, disruption to ground-nesting birds.
Woody weeds	Cutting	600–2000	Weakens rather than kills; allows herbicides to be used.	Pollution, disruption to ground-nesting birds.
	Herbicides	150–1500	Very effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.
Rhododendron	Cutting	700–3000	Allows herbicides to be used.	Pollution, disruption to ground-nesting birds.
	Herbicides	150–1500	Sometimes effective.	Poisoning, soil and water pollution, impacts on non-target flora and fauna.

[a] Lowest cost is for one-off control, highest cost for repeated control until tree establishment. For comparison purposes, costs refer to expense of treating 100 % of the area of 1 ha of ground over a 5-year establishment period. If spot or band weeding were practised, costs would reduce accordingly. For example, for trees planted at 2 m x 2 m spacing, if a 1 m spot around each tree is treated, actual cost per ha would reduce by 80 % (i.e. a mulch cost of €5500 becomes €1100).

Table 18.6 I Main herbicides used in British forestry.

Herbicide	Estimated GB annual usage (kg active ingredient) [a]
Glyphosate	14 400
Asulam	6 400
Propyzamide	4 000
Atrazine [b]	4 500
Imazapyr [b]	1 450
Metazachlor	430
Cyanazine [b]	430
2,4-D	340
Pendimethalin	340
Clopyralid	170

[a] Estimated usage only, based on state forests as 35 % of the total, in 2000.
[b] Atrazine, imazapyr and cyanazine are no longer approved.

Barriers to adopting alternative methods

Economic pressures have probably had the greatest effect to date in reducing the amount of pesticides used in UK woodlands. Legislation and other initiatives such as the UK Woodland Assurance Standard have, so far, probably only had additional but more limited impact on levels of usage. This may again be due to economic considerations. For the majority of pest and weed problems in UK forestry a non-chemical method of management already exists, but in most cases the available alternatives are at least a factor of ten to a hundred times more expensive than using pesticides (Willoughby *et al.,* 2004).

The reduction in available products, and the adoption of certification initiatives, will result in managers being faced with increasing pressure to reduce pesticide usage in the future. However, there is little immediate likelihood of more resources becoming available to fund this change in practice.

Research into alternatives to pesticide use has taken place over many years in the UK, but one barrier to the adoption of alternatives to herbicides may be that, in the past, information relating to individual pest, disease, vegetation and wildlife problems has often been published separately. More recent guidance (Willoughby *et al.,* 2004) aims to address this by providing a decision framework to allow managers to take an integrated approach to reducing chemical use when dealing with these damaging agents, and to determine the method of management that is likely to have the least impact on the environment.

Ongoing research

Current research includes investigations into direct seeding (Photo 18.3, page XXX) as a method of reducing herbicide inputs, identification of alternatives to the use of withdrawn herbicides such as the triazines, control of specific invasive weeds such as bramble and rhododendron, and the use of alternative mulch products. Research efforts are currently under way in the UK to evaluate the potential for biological control of Japanese knotweed (*Fallopia japonica*) and Himalayan balsam (*Impatiens glandulifera*). With respect to Japanese knotweed, three natural enemies from the centre of origin of the plant have already been identified as potential classical biocontrol agents and are currently undergoing rigorous host specificity testing. Options for the control of the invasive alien weed giant hogweed (*Heracleum mantegazzianum*) were assessed within a multidisciplinary EU project which ended in 2005. However, none of the insects or fungal pathogens collected in the plant's native area in the Caucasus proved to exhibit sufficient host specificity to be considered for introduction as a classical biological agent into Europe.

Future research needs/potential for European collaboration

Some examples of requirements for future research in Britain, that may be amenable to European collaboration, include: the use of cover plants, biodegradable mulch materials, alternative herbicides, control of invasive species such as bramble, bracken, Japanese knotweed, rhododendron and grasses, and the use of direct seeding for restoration of native woodlands (Photo 18.3, page 156). A number of plant species alien to both Britain and Europe have been identified as suitable targets for the development of classical biological control approaches (Sheppard *et al.,* 2006), or mycoherbicides (Green, 2003).

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding. Current European and national legislation does not facilitate biological weed control, and may thus discourage some potential funders. However, a number of European initiatives have recently been set up in order to address these regulatory and legislative issues, with the aim of making biological control of invasive alien weeds a viable concept for Europe.

Ecosystem responses

Current knowledge

Effects of weeds on trees

In Britain, the main areas of concern are the effects of competition from weeds for soil moisture and nutrients, and to a lesser extent light competition and the physical smothering of tree seedlings. However all of these factors vary with the nature of the site and the weed species present. Competition effects are revealed by reduction in tree growth and survival, the latter occurring particularly where trees are under stress from other factors, and on hotter, drier sites in the east and south of the country. Weeds may also have indirect effects, for example providing habitat for animals that prevent regeneration by eating seed and seedlings, and creating unfavourable conditions at the soil surface, for example by leaving a dense cover of organic material.

Nature and magnitudes of effects

Research has shown that effects vary depending on, in particular, site, tree species and weed species (Davies, 1987), but many of these relationships have yet to be adequately defined and synthesized for British conditions, especially for restocking by natural regeneration in woodland environments. Invasive weeds can have significant effects on important ground flora species that are often highly prized components of semi-natural ecosystems.

Impacts of control methods

These impacts are outlined in Table 18.5.

Ongoing research

Research within the Forestry Commission is taking place on the relative competitiveness of different weed species, critical periods of weed competition, and the ecology of weed species.

Future research needs/potential for European collaboration

Some examples of requirements for future research in Britain, that may be amenable to European collaboration, include:

- Developing a greater understanding of the biology, ecology and competitive effects of invasive species such as bramble, bracken and grasses under current and future climate change scenarios.
- Deriving an improved understanding of the competitive relationships between different species of trees and weeds.
- Developing models to predict the response of weeds and tree seedlings to different silvicultural treatments on different sites in order to aid decision making and planning of forest management.

Barriers to carrying out future research

Progress with future research could be hampered by lack of funding.

Society and vegetation management

Current knowledge

Little formal research appears to have been carried out into the social dimensions of vegetation management within woodlands in Britain.

Ongoing research

Social research programmes are focusing on issues such as accessibility and racial equality, health, governance and public involvement and social and cultural values.

Future research needs

There is a need for research into attitudes and perceptions of risk for forest vegetation management practices and possible alternatives.

Barriers to carrying out future research

In addition to sourcing funding, researchers interested in participating in such investigations need to be identified in the UK.

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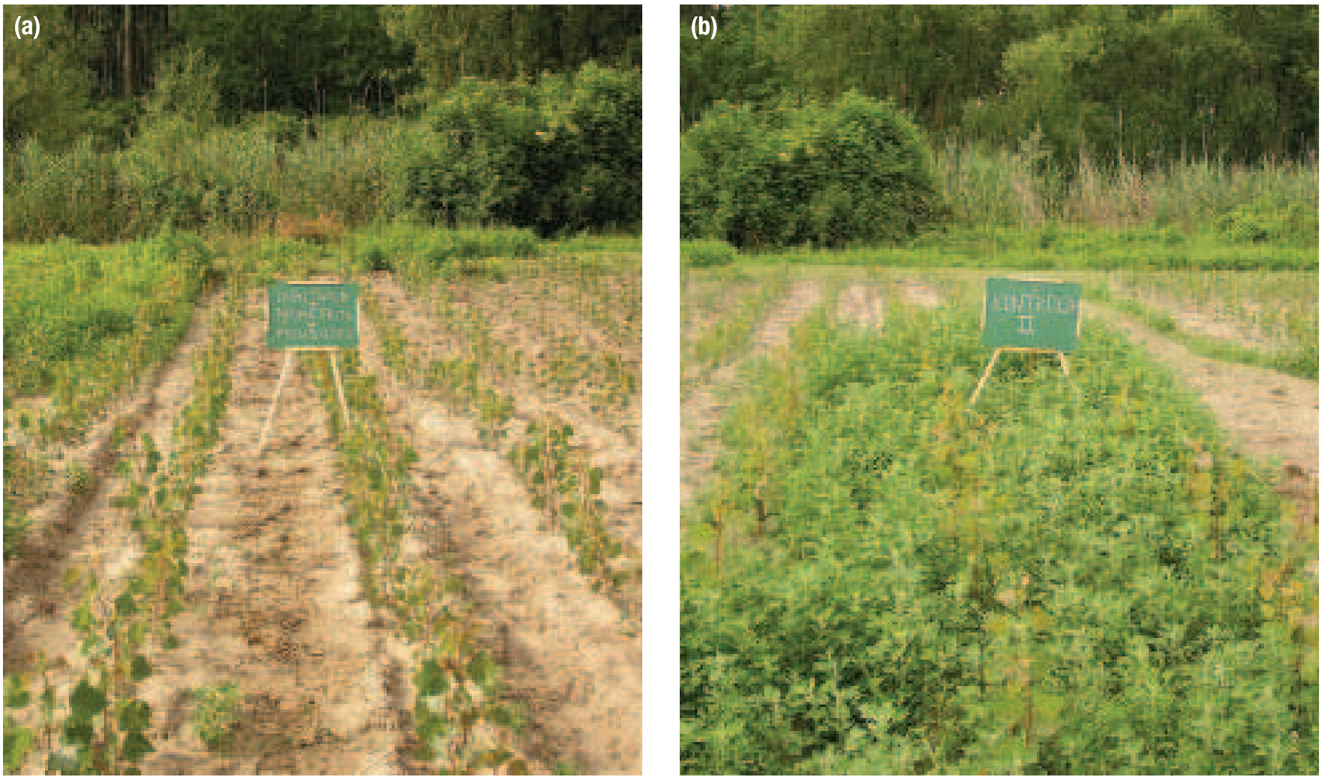
Romania Photo 13.1 | Manually sown and weeded silver-fir crop in Timisu de Sus forest nursery, Brasov county.

Romania Photo 13.2 | Mechanized cultivation between rows of seedlings in a young plantation in Murfatlar Forest District, Constanta county.

Serbia Photo 14.1 | Herbicide trials in a poplar nursery **(a)** efficiency of herbicides applied; **(b)** control plot.



Serbia Photo 14.2 | Weed control by herbicides in a poplar nursery.

Serbia Photo 14.3 | Weed control by herbicides in the rows of a poplar plantation.

Slovak Republic Photo 15.1 | Dense weed growth following windthrow is a problem for natural regeneration (J. Varinský).

Slovak Republic Photo 15.2 | Application of Casoronom G (dichlobenil) for protection of young broadleaved trees (J. Varinský).

Spain Photo 16.1 | Mediterranean Holm oak (*Quercus ilex* subs. *ballota*) and black pine (*Pinus nigra* subsp. *salzmannii*) mixed forest in Odèn, Solsona, Lleida (David Guixé).

Spain Photo 16.2 | Stone pine *(Pinus pinea)* plantation on former agricultural land in Vilviestre de Muñó, Burgos (José Ramón González).

Sweden Photo 17.1 | Natural regeneration of a Scots pine *(Pinus sylvestris)* stand using the uniform shelterwood system (Magnus Löf).

Sweden Photo 17.2 | Control of insects by spreading herbicides from the air (Helge Jonsson).

United Kingdom Photo 18.1 | Rhododendron, a non-indigenous evergreen shrub, invading heath and young woodland in Kincardine, Scotland (Forestry Commission Picture Library/Isobel Cameron).

United Kingdom Photo 18.2 | Excavator cultivation on an upland restock site to improve tree establishment and suppress weed vegetation (Forestry Commission/Alistair Macloed).

United Kingdom Photo 18.3 | Direct seeded predominantly native woodland mix – oak, ash, cherry, hazel, hawthorn, field maple, plus sweet chestnut and sycamore – after four growing seasons, 2 m pole in foreground. Shows variation in structure and naturally occurring open space, as advocated for new native woodlands (Forestry Commission Picture Library/George Gate).